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ABSTRACT

In this first issue of the journal, the educational imperatives of the evolving energy situation are discussed in an editorial. Background on energy issues are provided for the teacher. Opportunities for developing energy education teaching units are discussed. A segment of the journal presents recent developments in energy education. A segment entitled "Energizing Your Curricula" provides energy ideas, activities, and projects for classroom use. A final section provides a listing of books, films, games, and instructional kits for energy education. (RE)

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THE JOURNAL OF ENERGY EDUCATION

Devoted to the Development of An Energy Literate Society

Vol. 1, No. 1 *Winter, 1978*

IN THIS ISSUE

Entering the New Energy Era: The Education Imperative - Editorial

The Forgotten Fundamentals of the Energy Crisis - article

The Energy Dilemma - A View from the Electric Utilities - article

Colorado's Adult Energy Education Project - report

What's New in Energy Education?

Energy and Man's Environment - Portland, Oregon
National Science Teacher's Association - Washington, D.C.
Biological Science Curriculum Study - Boulder, Colorado

Energizing your Curricula - Ideas/Activities for Immediate Classroom Implementation.

Review of New Materials

Opinionnaire

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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Charles A. Bottinelli

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) AND USERS OF THE ERIC SYSTEM."

Research Articles, Project Reports, Curriculum Enrichment Materials and Instructional Strategies Designed to Promote Awareness, Knowledge and Concern of the Energy Dilemma in K-Adult Classrooms.

SE 026 321

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Volume 1, Number 1 *Winter, 1978*

Editorial — Entering A New Energy Era — The Education Imperative	2	Charles A. Bottinelli
The Forgotten Fundamentals of The Energy Crisis	4	Albert A. Bartlett
Teacher Background Up-Date — The Exponential Function	18	
The Energy Opportunity — A View from An Electric Industry	20	Herrick J. Young
Reflections on an Energy Education Venture: Colorado's Adult Energy Education Program	24	Harold M. Anderson
WHAT'S NEW IN ENERGY EDUCATION?		
Energy & Man's Environment	31	John Jones
NSTA Energy Education Program	34	John Fowler
Energy & Society: Investigations in Decision Making	38	Faith Hickman
ENERGIZING YOUR CURRICULA		
Modeling Exponential Growth	41	John Christensen
Where Have All the Calories Gone?	49	Mark Terry and Paul Witt
Fluorescent vs. Incandescent Lighting	50	U.S. Department of Energy
Heat Absorbed by a Closed Automobile	51	Thomas W. Norton
Elements of the Good Life Web	55	Energy & Man's Environment
RECHARGING YOUR LIBRARY: ABSTRACTS/REVIEWS/RESOURCES	56	
OPINIONNAIRE		

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EDITORIAL

ENTERING A NEW ENERGY ERA — THE EDUCATION IMPERATIVE

"To prophesy is extremely difficult — especially with respect to the future."

Chinese proverb

TRANSITIONS to new sources of energy are not unique to our society. Approximately sixty years following the pre-industrial peaking of firewood as a major fuel source, coal — abundant, accessible and inexpensive — began to emerge (ca. 1880) as the primary energy resource, firing the Industrial Revolution. With the advent of discoveries of vast reserves of petroleum, petroleum liquids and natural gas, our "fuel mix" began another radical transition and coal production began declining in 1910, becoming a secondary fuel source (ca. 1940) approximately sixty years after it had replaced wood. This decade is witness to another transition: as the domestic reserves of oil and natural gas decline precipitously at frightening rates, our Super Industrial Society is turning toward a yet fully undetermined fuel mix, a mix which appears to rely heavily on nuclear fission, coal — the one remaining fossil fuel still in relatively great abundance, energy conservation efforts and, to much lesser extents, on other, more exotic technologies such as solar photovoltaic, geothermal, ocean thermal energy conversion, wind and biomass.

There is something, however, that seems foreboding about this transition in particular. During the past half-century, each change to a new energy fuel has brought our society to new heights in standards of living, to new vistas of products we never dreamed possible and to enormously increased levels of technological advancement (and dependence) — the envy of the Third World. Yet this progress would not have been achieved if it were not for easy accessibility to the fossil fuels, primarily oil and natural gas. M. King Hubbert, one of this country's most respected geophysicists and resource experts, has plotted a graph depicting fossil fuel consumption as a function of time from 5000 BC to 5000 AD. The pinched, approximately normal curve of fossil fuel exploitation appears as not much more than a candle's flicker in the dark abyss of time. Domestic oil production and natural gas production have already peaked, and we are urged to fill the deficit with drastically increased coal production. With a U. S. population of 215 million, the birth rate apparently on the rise again and electrical consumption doubling every ten years, what will substitute for our increasing dependence on the fossil fuels and their countless derivatives? Indeed, can we afford to further combust those reserves at the rates urged in Washington?

We were warned by proponents of the Environmental Movement as far back as April, 1970 — the first Earth Day — that our society would be facing massive shifts in life styles due to a complex assortment of assaults on the biosphere, not the least of which was (and still is) related to an exponentially increasing consumption of energy for all end uses. Almost a decade's worth of rhetoric has had little effect on our society's knowledge base, attitudes and behavior.

What is especially worrisome is that a large fraction of the public is behaving as though no energy problem exists. Witness the record sales of summer gasoline and August automobiles. Consider also that electrical consumption so far this year is over 7% of that of one year ago. A poll conducted as late as September indicated that few citizens are fully aware of the dimensions of the energy dilemma. For example, only 48% of those surveyed know that we must import oil; even many of our best educated think domestic oil production fully satisfies our demands.* Seventy-four per cent of respondents in the non-high school graduate group believed that there is no energy problem, in contrast to 42% for college graduates. To compound a worsening credibility gap, our representatives in Washington appear to be succeeding in further weakening Carter's original energy policy — a policy which lacked teeth in the beginning.

In the past our society has looked toward education to accelerate changes in attitudes, a prerequisite of adapting to new conditions consistent with crisis resolution. Yet we are all painfully aware of the inordinate time lag between crisis and classroom implementation of appropriate learning strategies. It is imperative that educators begin now to prepare citizens to cope with future realities consistent with the perceived requirements of the new energy era; it is imperative that we increase efforts to instruct adults in energy basics, convincing them that the energy crisis is not contrived and will not be "wished away"; it is imperative that energy become a central theme, around which all disciplinary fabrics are woven; it is imperative that students be introduced to the wide and diverse scope of career options associated with old and anticipated energy technologies; and it is imperative that we inculcate in our citizens a knowledge of the fundamentals and an appreciation of the limits implicit in exponential growth on a planet of finite resources.

Moreover, once an adequate knowledge foundation exists, students and adults must be motivated to become actively involved in helping to determine the immediate- and long-term directions of our energy policies and technologies, and they must be urged to voluntarily adapt to a conservation ethic consistent with an age of dwindling metal and mineral reserves.

The challenge to budge a lethargic, disbelieving society from a nation of profligate energy consumers toward one which is energy literate rests primarily with educators; yet this task cannot be accomplished by education alone. We must strive toward the goal of energy literacy, working cooperatively with and enlisting the aid of business, industry and governmental agencies; isolated efforts will not succeed in time.

Alvin Toffler observed that all education stems from some vision of the future, and that if the image of the future held by society is grossly inaccurate, its educational system will betray its youth. Unlike the Chinese proverb, we have sufficient data now to visualize a future of harsh energy realities. We must begin educating for that future now. The handwriting is on the wall. — Charles A. Bottinelli.

*A. J. Parish, NEW YORK TIMES, 1 September, 1977, p. 1.

Exponential Growth

THE FORGOTTEN FUNDAMENTALS OF THE ENERGY CRISIS

Albert A. Bartlett

Dr. Bartlett is Professor of Physics at the University of Colorado at Boulder and is president of the American Association of Physics Teachers. *His paper was presented at the Third Annual Conference on Energy at the University of Missouri at Rolla, and was published in their proceedings (UMR-SMEC, Vol. 3, pp. 10-19, October, 1976). It has been edited and reprinted with permission.*

(Editor's Note: The reader is urged to see the October, 1976 issue of THE PHYSICS TEACHER *for the beginning of a series of articles concerning the exponential function, also written by Dr. Bartlett.)*

"Facts do not cease to exist because they are ignored."

Aldous Huxley

1. INTRODUCTION

We hear political leaders of the United States speaking of "energy self-sufficiency" and of "Project Independence". We have the vague feeling that arctic oil from Alaska will relieve the energy crisis, and we are told that the United States is in good shape in the long run because of our vast deposits of coal. What are the facts?

Rather than take you into the sticky abyss of statistics, I wish to rely on a few data and the pristine simplicity of elementary mathematics. With these basic tools I believe I can give you a new and reasonably clear understanding of the gravity of the energy problem.

2. MATHEMATICAL BACKGROUND; A REVIEW

When a quantity (such as the rate r(t) of consumption of a resource) grows a fixed percent per year, the growth is exponential

$$r(t) = r_0 e^{kt} \quad (1)$$

where r_0 is the current rate of consumption (at t=0), e is the base of natural logarithms, and k is the fractional growth per year. The quantity r(t) will grow to twice its initial value in a time $T = (\ln 2)/k = 70/P$ where P, the percent growth per year, is 100k. The constancy of the doubling time of the growth means that in one doubling time the growing quantity will double in size, in two doubling times it will quadruple, in three doubling times it will grow by a factor of $2^3 = 8$, in four doublings it will grow by a factor of $2^4 = 16$, etc. It is natural then that we talk of growth in terms of powers of two.

"The world's most important arithmetic is the arithmetic of the exponential function."

3. THE POWER OF POWERS OF TWO

If you place one grain of wheat on the first square of a chessboard, 2 on the second, 4 on the third, 8 on the fourth, 16 on the 5th, etc. you will have 2^{63} grains on the 64th square and the total grains on the board will be one grain less than 2^{64}. How much wheat is 2^{64} grains? Simple arithmetic shows that it is approximately 500 times the current annual harvest of wheat in the entire world; an amount that is probably larger than all the wheat that has been harvested in the history of the earth! How did we get to this enormous number?. We started with one grain of wheat and we doubled it a mere 63 times!

Exponential growth is characterized by doubling, and a few doublings can lead us quickly to enormous numbers.

Populations tend to grow exponentially. The world population today is estimated to be 4 billion people and it is growing at the rate of 1.9 percent per year. It is easy to calculate that at this rate the world population will grow by one billion in less than 12 years, the population will double to 8 billion in 36 years, the population would grow to a density of one person per square meter on the dry land surface of the earth (excluding Antarctica) in 550 years, and the mass of people would equal the mass of the earth in a mere 1620 years! Tiny growth rates can yield incredible consequences!

Compound interest on your savings account causes the account balance to grow exponentially. One dollar at an interest rate of 5% per year compounded continuously will grow in 500 years to $72,000,000,000 and today the interest would be coming in at the magnificent rate of $117 a second.

Steady inflation causes prices to rise exponentially. An inflation rate of 6% per year will, in 70 years, cause prices to increase by a factor of 64! If the inflation continues at this rate the $0.40 loaf of bread we feed our toddlers today will cost $25.60 when the toddlers are retired and living on their pensions! It has even been proven that the number of miles of highway in the country tends to grow exponentially (3).

4. EXPONENTIAL GROWTH IN A FINITE ENVIRONMENT

Bacteria multiply by division (that sounds odd, doesn't it?) so that one bacterium becomes 2, the two divide to give 4, the 4 divide to give 8, etc. For a certain strain of bacteria the time for this division is one minute. This is recognized as being exponential growth with a doubling time of one minute. I put one bacterium in a bottle at 11:00 AM and I observe that the bottle is full at noon. Here is a simple example of exponential growth in a finite environment. This is mathematically identical to the case of the exponentially growing consumption of our finite resources of fossil fuels. Keep this in mind as you ponder three questions about bacteria:

(1) When was the bottle half-full? Answer: 11:59 AM.

(2) If you were an average bacterium in the bottle, at what time would you first realize that you were running out of space? There is no unique answer to this question, so let me ask "At 11:55 AM, when the bottle is only 3% filled and is 97% empty, how many of you would perceive that there was a problem?"

Suppose that at 11:58 some farsighted bacteria realize that they are running out of space in the bottle and, consequently, with a great expenditure of effort and funds, they launch a search for new bottles. They look offshore and in the Arctic, and at 11:59 AM they discover three new empty bottles. Great sighs of relief come from all

the worried bacteria, because this magnificient discovery is three times the number of bottles that had hitherto been known. The discovery quadruples the total space resource known to the bacteria. Surely this will solve the problem so that the bacteria can be self-sufficient in space. The bacterial "Project Independence" must now have achieved its goal.

(3) How long can the bacterial growth continue if the total space resources are quadrupled? Answer: Two more doubling times (minutes)!

Table 1 documents the last minutes in the bottles.

Table 1

The Effect of the Discovery of New Bottles

11:58 AM	Bottle No. 1 is one quarter full.
11:59 AM	Bottle No. 1 is half-full.
12:00 Noon	Bottle No. 1 is full.
12:01 PM	Bottles No. 1 and 2 are both full.
12:02 PM	Bottles No. 1, 2, 3, 4 are all full

Quadrupling the resource extends the life of the resource by only two doubling times! When consumption grows exponentially, enormous increases in resources are consumed in very short times!

5. THE LENGTH OF LIFE OF A FINITE RESOURCE WHEN THE RATE OF CONSUMPTION IS GROWING EXPONENTIALLY

Physicists would tend to agree that except for sunlight, the world's resources are finite. The extent of the resources is only incompletely known, although knowledge about the extent of the remaining resources is growing very rapidly. The consumption of resources is generally growing exponentially. Let us plot a graph of the rate of consumption r(t) of a resource (in units such as tons per year) as a function of time measured in years. The area under the curve in the interval between times t = O (the present, where the rate of consumption is r) and t = T will indicate the total consumption C in tons of the resource in the time interval. This is stated mathematically

$$C = \int_{t=o}^{t=T} r(t)\,dt \qquad (2)$$

If resource consumption follows Eq. 1, then the total resource consumed in the interval t=0 to t=T is

$$C = \frac{r_o}{k}\left[e^{kt} - 1\right] \qquad (3)$$

If the known size of the resource is R tons, we can determine the time T_e for t in Eq. 3.

$$R = \frac{r_o}{k}\left[e^{kT_e} - 1\right] \qquad (4)$$

We may solve this for Te to obtain

$$T_e = \frac{1}{k}\ln\left[\frac{kR}{r_o} + 1\right] \qquad (5)$$

This equation is valid for all positive values of k and for those negative values of k for which the argument of the logarithm is positive. *I suspect that Eq. 5 and its application to the resources of this nation and of the world constitute the best kept scientific secret of the century.*

6. HOW LONG WILL OUR FOSSIL FUELS LAST?

The question of how long our resources will last is perhaps the most important question that can be asked in a modern industrial society.

Dr. M. King Hubbert, a geophysicist with the United States Geological Survey in Reston, Va. is a world authority on the estimation of energy resources and on the prediction of their patterns of discovery and depletion. Many of the data used here come from Hubbert's reports (4, 5). The three figures in this paper are redrawn from figures in his papers. These reports are required reading for anyone who wishes to understand the fundamentals and many of the details of the problem.

Table 2 gives statistics on production of crude oil in the United States.

Table 2

United States Crude Oil (lower 48 States)

Units are 10^9 barrels
(1 barrel = 42 U. S. gallons = 158.98 liters)

Ultimate Production	190
Produced to 1972	96.6
Percent of Total Production produced to 1972	50.8%
Annual Production Rate, 1970	3.29

Note that since one-half of our domestic petroleum has already been consumed, *the "petroleum time" in the U.S. is one minute before noon!* Figure 1 shows the historical trend in domestic production of crude oil. Note that from 1870 to 1929 the rate of production of domestic crude oil increased exponentially at a rate of 8.27 percent per year with a doubling time of 8.4 years. If the growth in the rate of production stopped and the rate of production were held constant at the 1970 rate, the remaining U.S. oil would last only 28 years!

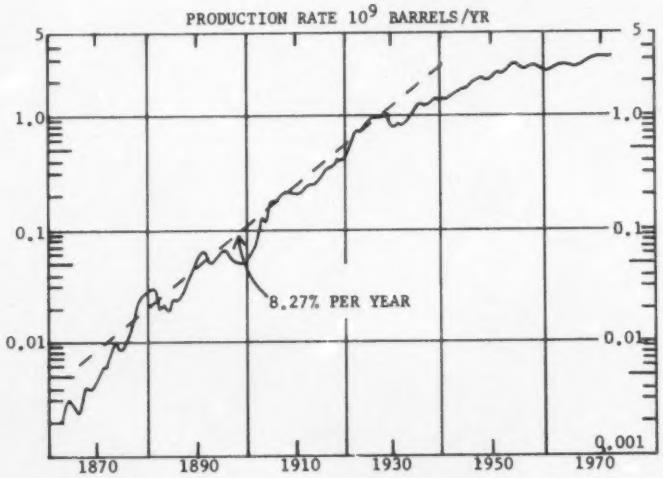

Table 3

Life Expectancy in Years of Various Estimates of U.S. Oil Reserves for Different Rates of Growth of Annual Production

(Units are 10^9 barrels)

This table is prepared by using Eq. 5 with r_0 = 3.29 B barrels per year. Note that this is domestic production which is only about one half of domestic consumption.

Col. 1: the percent annual growth rate.

Col. 2: the lifetime of the resource which is calculated using R = 190-96.6= 93.4 as the estimated oil remaining in the lower 48.

Col. 3: the lifetime calculated using R = 93.4 + 10 to include the Alaskan oil.

Col. 4: the lifetime calculated using R = 93.4 + 10 + 103.4 = 206.8 to include Alaskan oil and a hypothetical estimate of U.S. oil shale..

Col. 1	Col. 2	Col. 3	Col. 4
Zero	28.4 yrs	31.4 yrs	62.8 yrs
1	25.0	27.3	48.8
2	22.5	24.4	40.7
3	20.5	22.1	35.3
4	19.0	20.4	31.4
5	17.7	18.9	28.4
6	16.6	17.7	26.0
7	15.6	16.6	24.1
8	14.8	15.7	22.4
9	14.1	14.9	21.1
10	13.4	14.2	19.9

The vast shale oil deposits of Colorado and Wyoming represent an enormous resource. Hubbert reports that the oil recoverable under 1965 techniques is 80 x 10^9 barrels, and he quotes other higher estimates. In the preparation of Table 3, I used the figure 103.4 x 10^9 barrels as the estimate of U.S. shale oil so that the reserves used in the calculation of Col. 4 would be twice those that were used in the calculation of Col. 3. This table makes it clear that *when consumption is rising exponentially, a doubling of the remaining resource results in only a small increase in the life expectancy of the resource.*

Anyone who wishes to talk about energy self-sufficiency in the United States must understand Table 3 and the exponential function upon which it is based.

Table 4 gives statistics on world production of crude oil.

Table 4

World Crude Oil, Data

Units are 10^9 barrels.	
Ultimate total production (4)	1952
Produced to 1972	261
Percent of total production produced to 1972 (4)	13.4%
Annual Production Rate, 1970	16.7

Note that a little more than one-eighth of the world oil has been consumed. *The "world petroleum time" is between two and three minutes before noon, i.e. we are between two and three doubling times from the expiration of the resource.*

Fig. 2 shows the historical trend in world crude oil production. *Note that from 1890 to 1970 the production grew at a rate of 7.04 percent per year, with a doubling time of 9.8 years.* It is easy to calculate that the world reserves of crude oil will last 101 years *at the 1970 level of production.*

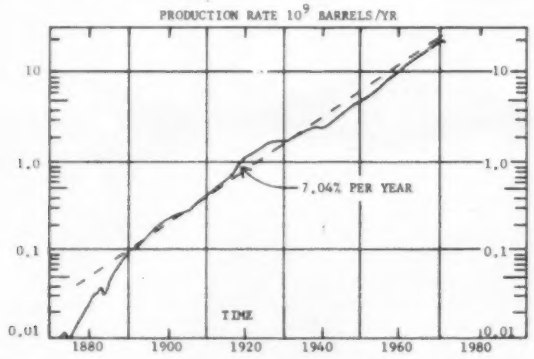

Table 5 shows the life expectancy of world crude oil reserves for various rates of growth of production and shows the amount by which the life expectancy is extended if one adds world deposits of oil shale. Column 4 is based on the assumption that the available shale oil is four times as large as the value reported by Hubbert. Note again that the effect of this very large hypothetical increase in the resource is very small.

Table 5

Life Expectancy in Years of Various Estimates of World Oil Reserves for Different Rates of Growth of Annual Production

Units are 10^9 barrels.

This table is prepared by using Eq. 5 with r_0 = 16.7 B barrels per year.

Col. 1: the percent annual growth rate of production.
Col. 2: the lifetime of the resource calculated using R = 1691 as the estimate of the amount of the remaining oil.
Col. 3: the lifetime calculated using R = 1691 + 190 = 1881 representing crude oil plus oil shale.
Col. 4: the lifetime calculated using R = 1691 + 4(190) = 2451 which assumes that the amount of shale oil is four times the amount which is known now.

Col. 1	Col. 2	Col. 3	Col. 4
Zero	101 yrs	113 yrs	147 yrs
1	69.9	75.4	90.3
2	55.3	59.0	68.5
3	46.5	49.2	56.2
4	40.5	42.6	48.2
5	36.0	37.8	42.4
6	32.6	34.1	38.0
7	29.8	31.2	34.6
8	27.6	28.8	31.8
9	25.7	26.8	29.5
10	24.1	25.1	27.5

From these calculations we can draw a general conclusion of great importance.

When we are dealing with exponential growth, we do not need to have an accurate estimate of the size of a resource in order to make a reliable estimate of how long the resource will last.

As the reader ponders the seriousness of the situation and asks, "what will life be like without liquid petroleum products?", the thought arises of heating homes electrically or with solar power and of traveling in electric cars. A far more fundamental problem becomes apparent when one recognizes that modern agriculture is based on petroleum-powered machinery and on petroleum-based fertilizers. This is reflected in a definition of modern agriculture.

Modern agriculture is the use of land to convert petroleum into food.

ITEM: "We have now reached the point in U.S. agriculture where we use 80 gallons of gasoline or its equivalent to raise an acre of corn, but only nine hours of human labor per crop acre for the average of all types of produce." (6)

It is clear that agriculture as we know it will experience major changes within the life expectancy of our students. With these changes could come a major further deterioration of world-wide levels of nutrition; yet we still have people who proclaim that Malthus has been proven to be wrong!

It has frequently been suggested that coal will answer the U.S. and world energy needs for a long period in the future. What are the facts?

Table 6 shows data on U.S. coal production that are taken from several sources.

Table 6

United States Coal Resource

Units are 10^9 metric tons.	
Ultimate Total Production (4)	
High estimate	1486
Low estimate	390
Produced through 1972 (my estimate from Hubbert's Fig. 22)	50
Percent of ultimate production produced through 1972:	
Percent of High estimate	3%
Percent of Low estimate	13%
Coal resource remaining:	
High estimate	1436
Low estimate	340
Annual Production rate, 1972	0.5
Rate of export of coal, 1974	0.06
Annual Production Rate, 1972	.6
Projected Future Rates of Production	
Annual Production Rate 1980	1.3
Annual Production Rate 1985	2.1

Fig. 3 shows the history of coal production in the U.S. Note that from 1860 to 1910, U.S. coal production grew exponentially at 6.69 percent per year (T_2 = 10.4 years). The production then leveled off at 0.5 x 10^9 tons per year which held approximately constant until 1972 whereupon the rate started to rise steeply. The

1974 datum and the governmental goals for 1980 and 1985 are shown with crosses. Coal consumption remained level for 60 years because our growing energy demands were met by petroleum and natural gas. From the data of Table 6 we can estimate the average annual rates of growth of coal production as represented by the government's production goals:

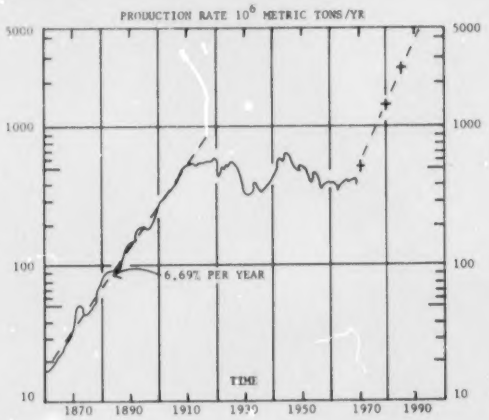

Table 7

Production Growth Rate Estimates

1974 to 1980	13%
1980 to 1985	9.6%
1974 to 1985	11%

Table 8 shows how long the two estimates of U.S. coal reserves will last for various rates of increase of the rate of production, as calculated from Eq. 5.

Table 8

Lifetime in Years of United States Coal

The lifetime in years of U.S. coal reserves (both the high and low estimate) are shown for several rates of growth of production from the 1972 level of 0.5 x 10^9 metric tons per year.

	High Estimate	Low Estimate
Zero	2872 yrs	680 yrs
1	339	205
2	203	134
3	149	102
4	119	83
5	99	71
6	86	62
7	76	55
8	68	50
9	62	46
10	57	42
11	52	39
12	49	37
13	46	35

Even a modest exponential growth of the rate of consumption of coal will consume the "vast U.S. reserves" of coal in a very short time.

7. WHAT DO THE EXPERTS SAY?

Now that we have seen the facts, let us examine what some branches of our federal government say about coal.

"It is clear, particularly in the case of coal, that we have ample reserves." "We have an abundance of coal in the ground. Simply stated, the crux of the problem is how to get it out of the ground and use it in environmentally acceptable ways and on an economically competitive basis."

"At current levels of output and recovery these reserves can be expected to last more than 500 years." (7)

Here is one of the most dangerous statements in the literature. It is dangerous because news media and the energy companies pick up the idea that

"United States coal will last over 500 years"

while the media and the energy companies forget or ignore the important caveat with which the sentence began,

"At current levels of output"

The right hand column of Table 8 shows that at zero rate of growth of consumption even the low estimate of the size of the U.S. coal resource "will last over 500 years", but if the government's initial plan of increasing coal production at an annual rate of 13 percent is maintained without change, then the low estimate of the U.S. coal resource, will be gone in 35 years!

It is absolutely clear that the government does not plan to hold coal production constant "at current levels of output."

"Coal reserves far exceed supplies of oil and gas, and yet coal supplies only 18 percent of our total energy. To maintain even this contribution we will need to increase coal production by 70 percent by 1985, but the real aim — to increase coal's share of the energy market will require a staggering growth rate" (8)

While the government is telling us that we much achieve enormous increases in the rate of coal production, other governmental officials are telling us that we can increase the rate of production of coal *and* have the resource last for a very long time.

"The trillions of tons of coal lying under the United States will have to carry a large part of the Nation's increased energy consumption, says (the) Director of the Energy Division of the Oak Ridge National Laboratories."

"He estimated America's coal reserves are so huge, they could last 'a minimum of 300 years and probably a maximum of 1000 years'". (9)

While we read these news stories we are bombarded by advertisements which say that coal will last a long time at present rates of consumption *and* which say at the same time that we must dramatically increase our rate of production of coal.

"At the rate the United States uses coal today, these reserves could help keep us in energy for the next two hundred years."

"Most coal used in America today is burned by electric power plants-(which)-consumed about 400 million tons of coal last year. By 1985 this figure could jump to nearly 700 million tons." (10)

Other advertisements stress just the 500 years (no caveat)

"We are sitting on half the world's known supply of coal — enough for over 500 years." (11)

Some ads stress the idea of self-sufficiency *without stating for how long a period we might be self-sufficient.*

"Coal, the only fuel in which America is totally self-sufficient." (12)

Other ads suggest a deep lack of understanding of the fundamentals of the exponential function.

"Yet today there are still those who shrill (sic) for less energy and no growth"

"Now America is obligated to generate more energy — not less — merely to provide for its increasing population" "With oil and gas in short supply, where will that energy come from? Predominantly from coal. The U.S. Department of the Interior estimates America has 23 percent more coal than we dreamed of. 4,000,000,000,000 (trillion!) tons of it. Enough for over 500 years." (the non-sentences are in the original) (13)

A simple calculation based on a current production rate of 0.6×10^9 tons per year shows that the growth in the rate of production of coal can't exceed 0.8 percent per year if the ad's 4×10^{12} tons of coal is to last for the ad's 500 years. Note that the 4×10^{12} tons cited in the ad is 2.8 times the size of the large estimate of U.S. coal reserves and is 12 times the size of the smaller estimate of U.S. coal reserves as cited by Hubbert.

We may *wish* that we could have rapid growth of the rate of consumption *and* have the reserves of U.S. coal last for a large number of years, but first-year college calculus is all that is needed to prove that these two goals are incompatible. At this critical time in our nation's history we need to shift our faith to calculations based on factual data and give up our belief in Walt Disney's First Law (14):

"Wishing will make it so."

On the broad aspects of the energy problem we note that the top executive of one of our great corporations is probably one of the world's authorities on the exponential growth of investments and compound interest. However he observes that "the energy crisis was made in Washington." He ridicules "the modern-day occult prediction" of "computer print-outs" and warns against extrapolating past trends to estimate what may happen in the future. He then points out how American free enterprise solved the great "Whale Oil Crisis" of the 1850's. With this example as his data base he boldly extrapolates into the future to assure us that American ingenuity will solve the current energy crisis if the bureaucrats in Washington will only quit interfering. (15)

We have ads by a major power company telling us that

"There is an increasing
scarcity of certain *fuels.*
But there is no scarcity of *energy.*
There never *has* been.
There never *will* be.
There never *could* be.
Energy is inexhaustible." (16)

(Emphasis is in the original).

We can read that a professor in a school of mining technology offers "proof" of the proposition

"Mankind has the right to
use the world's resources
as it wishes, to the limits
of its abilities—" (17)

We have the opening sentences of a major scientific study of the energy problem:

"The United States has an abundance of energy resources; fossil fuels (mostly coal and oil shale) adequate for centuries, fissionable nuclear fuels adequate for millenia and solar energy that will last indefinitely." (18)

We can read the words of an educated authority who asserts that there is no problem of shortages of resources.

"It is not true that we are running out of resources that can be easily and cheaply exploited without regard for future operations."

His next sentence denies that growth is a serious component of the energy problem.

"It is *not* true that we must turn our back on economic growth" (emphasis is in the original).

Three sentences later he says that there may be a problem.

"We must face the fact that the well of non-renewable natural resources is not bottomless." (19)

He does suggest that the lack of "leadership" is part of the problem.

We have the opening paper in an energy conference in which a speaker from a major energy company makes no mention of the contribution of growth to the energy crisis when he asserts that

"The core of the energy problem both U.S. and worldwide is our excessive dependence on our two scarcest energy resources — oil and natural gas."

For him continued growth is not part of the problem, it is part of the solution!

"*More* energy must be made available at a higher rate of growth than normal — in the neighborhood of 6 percent per year compared to a recent historical growth rate of 4 percent per year. (20)

And finally we note the Board Chairman of a major multinational energy corporation who concludes the discussion "Let's Talk Frankly About Energy" with his mild assessment of what we must do.

"Getting on top of the energy problem won't be easy. It will be an expensive and time-consuming task. It will require courage, creativeness and discipline—" (21)

When you compare the facts and the exponential calculations with the news stories, with the statements of public officials and with the statements in advertisements from energy companies, what can you conclude?

The only thing that is more distressing than the results of these exponential calculations is the observation that so few of our leaders, educators, policy makers, and "experts" have performed the calculations or show evidence of understanding the results.

8. AN EXPONENTIAL SOLUTION

The exponential function provides an interesting "solution" to the energy and resource problems. If we make the rate of production of a resource follow the curve

$$r(t) = r_o e^{-(r_o/R)t}$$

the total production from now to infinity is exactly equal to the size R of the resource, (2), (22). WE CAN USE THE RESOURCE AND HAVE IT LAST FOREVER! This is the ultimate self-sufficiency. For the large estimate of U.S. coal, the production rate would have to decrease approximately 3 percent per century in order to assure that U.S. coal would last forever. The difficulty our nation would face with this declining rate of production can be expressed in the question, "Could we live one year from now with coal production at the rate it was a day and a half ago?" This program can be applied to any resource. If r_o/R for world petroleum is

(1/101) then the decline in petroleum consumption would have to be about 1% per year to make petroleum last forever.

The greatest act of responsibility which we could perform for our descendants for all time would be to put our consumption of coal and other resources on this declining curve. Not only is it proper to save some resources for those who will follow us, but it may make the difference in national self-sufficiency and, ultimately, of national survival.

9. WHAT DO WE DO NOW?

1) We must educate all of our people to an understanding of the arithmetic and consequences of growth, especially in terms of the earth's finite resources. David Brower has observed that:

> **The promotion of growth is simply a sophisticated way to steal from our children.**

2) We must educate people to the critical urgency of abandoning our religious belief in the disastrous dogma that "Growth is good", that "Bigger is better", that "We must grow or we will stagnate", etc., etc. We must realize that growth is but an adolescent phase of life which stops when physical maturity is reached. If growth continues in the period of maturity it is called obesity or cancer. Prescribing growth as the cure for the energy crisis has all the logic of prescribing increasing quantities of food as a remedy for obesity or prescribing more cancer as the cure for cancer.

The occasion of our nation's 200th anniversary would be an appropriate time to make the transition from national adolescence to national maturity.

3) We must conserve in the use and consumption of everything. We must outlaw planned obsolescence. (We must recognize that, as important as it is to conserve, the *arithmetic shows clearly that improbably large savings from conservation will be wiped out in short times by even modest rates of growth.* Conservation alone can not do the job).

4) We must recycle almost everything. Except for the continuous input of sunlight the human race must finish the trip with the supplies that were aboard when the "spaceship earth" was launched.

5) We must invest great sums in research to

A) Develop the use of solar, geothermal, wind and tidal energy.
B) Reduce the problems of nuclear fission power plants.
C) Explore the possibility that we may be able to harness nuclear fusion and other sources of energy.

These investments must not be made with the idea that if they are successful they could sustain growth for a few more doubling times. They must be made with the goal that they could take over the energy load in a mature and stable society in which fossil fuels are used on a declining exponential curve that will let them last forever, and in which fossil fuels are no longer used to heat buildings but are saved for their much more important use as chemical raw materials.

6) We must recognize that it is pseudoscience and false technology to promote ever-increasing rates of consumption of resources in the hope that science and technology will rescue us from the consequences of our self-centered folly. It is not acceptable to base our national future on the motto,

"When in doubt, gamble."

7) We cannot sit back and deplore the lack of "leadership" and the lack of response of our political system. In the immortal words of Pogo,

"We have met the enemy, and they's us."

We are the leaders, and we are vital parts of the political system. Everyone of us has access to dozens of other leaders who have not yet understood the problem. We must take the message to all the people in the spirit of education and service to which we are completely committed.

The arithmetic makes clear what will happen if we hope that we can continue to increase our rate of consumption of fossil fuels. Some experts suggest that the system will take care of itself and that growth will stop naturally, even though they know that cancer, if left to run its course, always stops when the host is consumed. My seven suggestions are offered in the spirit of preventive medicine.

10. CONCLUSION

The preceding calculations are offered as guideposts which must be understood by those who would deal constructively with the energy crisis. These scientific calculations must be viewed in the light of the words of Gustav Lebon (1841-1931)

"Science has promised us truth
and understanding
of such relationships
as our minds can grasp.
It has never promised us either
peace or happiness."

Perhaps the most succinct conclusion that is indicated by the analysis above is, and again I use the immortal words of Pogo,

"The future ain't what it used to be!"

The American system of free-enterprise has flourished for 200 years for the benefit of all mankind. Until recently it has flourished in a world of infinite resources. The challenge of the decades ahead is set forth clearly in the question,

"Can free-enterprise survive in a finite world?"

Perhaps you can now appreciate why I say,

The greatest shortcoming
of the human race
is man's failure
to understand
the exponential function.

11. ACKNOWLEDGMENTS

Hundreds of conversations with dozens of people over six years have yielded many ideas, suggestions and facts which I have incorporated here. I offer my thanks to all who have helped in the evolution of these ideas.

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Teacher Background Up-Date

THE EXPONENTIAL FUNCTION

Derivation

The condition for exponential growth is satisfied when the rate of growth of a quantity N is proportional to the quantity itself, or

$\frac{\Delta N}{\Delta t} = kN$ (1) where k is the fractional change ($\Delta N/N$) in N per unit time (Δt).

E Eqn. (1) can be rearranged to yield

$\frac{\Delta N}{N} = k\Delta t$ or expressed in differentials as

$dN/N = k\, dt$ (2)

Integrating Eqn. (2) gives

$\ln N = kt + \ln N_0$ (3) where N_0 is the size of the quantity at time=0.

Allowing each side of Eqn. (3) to become the exponent of e, the base of natural logarithms (e = 2.718. . .), yields

$e^{\ln N} = e^{(kt + \ln N_0)}$ and, finally,

$N = N_0 e^{kt}$ (4) the classic form of the exponential function.

Doubling Time

If a quantity doubles its growth ($N/N_0 = 2$) in t_2 years, then

$2 = e^{kt_2}$ and

$t_2 = \ln 2/k \cong .70/k \cong 70/100k$ where 100k is the PERCENT annual growth rate.

Resource Depletion

If the rate of consumption dC/dt of a non-renewable resource is exponentially increasing, then Eqn. (4) can be written

$$dC/dt = r_o e^{kt} \qquad (5)$$ where r_o is the present production rate.

Integrating Eqn. (5) from the beginning of time (t_o) to a future time (T) will yield an area under the curve which represents the total resource consumed in this time interval

$$C = \int_{t=0}^{t=T} r_o e^{kt}\, dt = (r_o/k)\, e^{kt}\Big|_{t=0}^{t=T} = (r_o/k)\,(e^{kT} - 1) \qquad (6)$$

If an estimate of the reserve of a resource is known (R), then substitution of R for C in Eqn. (6) allows us to solve for T_e (T becomes T_e, the expiration time; i.e., the time required for ALL of the resource to be consumed).

$$R = (r_o/k)\,(e^{kTe} - 1)$$

$$Rk/r_o + 1 = e^{kTe} \qquad (7)$$

Taking the natural logarithm of both sides of Eqn. (7) yields

$$\ln\,(Rk/r_o + 1) = k\,T_e$$

$$T_e = \frac{1}{k} \ln\left(\frac{Rk}{r_o} + 1\right) \qquad (8)$$

Eqn. (8) is the expression used in determining the EXPONENTIAL RESERVE INDEX of a resource, in contrast to Eqn. (9) below which is used to calculate the STATIC RESERVE INDEX

$$T_s = R/r_o \qquad (9)$$

A Perspective

THE ENERGY OPPORTUNITY: A VIEW FROM AN ELECTRIC INDUSTRY

H. J. Young

Herrick J. Young is Senior Vice President of the Edison Electric Institute, the national trade association of investor-owned electric light and power companies.

Right now it is difficult to be optimistic about the prospects for the future of energy in this country. Recent studies all stress the gravity of inevitable shortages of oil and natural gas, roadblocks are thrown in the way of development of coal and nuclear power generating facilities, and new sources of energy continue to be just a vague blur on the horizon.

Those of us in the business of supplying electric energy must find a way to help people understand a few basic ideas. First, that the need for energy derives from the desires of people to have things or to do things that would not be possible through muscle power alone. And second, that electricity is a form of energy that is derived from raw fuels, some of which are limited in supply.

If this country is to have an adequate supply of electricity to meet its needs in the years and decades ahead, certain actions must be taken, certain roadblocks must be removed. The electric utility industry is working with a sense of optimistic realism that this can be accomplished.

Over the years, there has been a notable move to electric power in the United States.

In 1930, 10 percent of all the energy consumed was used to produce electricity. Today it is close to 30 percent, and by the year 2000 it is expected to be 50 percent.

This growth is anticipated because the applications of electricity will be increasing not only in new end uses but because electricity will substitute for the direct combusion of fuels that are in relatively short supply. Today emphasis must inevitably be on expanding the generating capacity of electricity from coal and nuclear fuels.

FOSSIL FUELS

Coal is one of our two most available resources. It provided about 46 percent of electric generation in 1976, and reserves in this country are sufficient to last for centuries, even at increased rates of consumption.

The most serious restrictions concerning the use of coal lie in restrictive environmental laws and regulations. When the Clean Air Act was passed in 1970, the motivation was positive. Everyone wanted clean air. However, Congress went too far and this legislation effectively placed much of our coal supply out of reach.

On August 7th of this year the President signed into law amendments to the Clean Air Act which are even more restrictive. They create difficult financial and administrative impediments not only for a large part of the electric utility industry but for industry as a whole. Our industry fully supports the desire to improve the air quality of the country, but unless the energy needs of the people and the nation are taken into consideration, the law will compound an already serious situation.

There are large quantities of low-sulfur coal in this country that can be burned to generate electricity while meeting all health standards. It makes no sense, either technologically or economically, to force plants using low-sulfur coal to add expensive and unnecessary scrubbers as well. And this is what the new amendments do. The cost of scrubbers is huge. Installing and operating them would drive up the price of electricity to consumers by $5 billion by 1985.

Conversion of existing oil and gas-fired units to coal also presents serious and costly problems. The transition to coal in areas faced with conversion would be very expensive and time-consuming, resulting in higher electricity rates to consumers. To convert existing and planned oil and gas-burning capacity expected to be in service by 1985 would necessitate an expenditure conservatively estimated at $50 billion in 1976 dollars.

Still, for years to come we will need to depend on coal converted to electricity to meet a major portion of our energy needs. All the avenues available to burn coal cleanly or to disperse the discharges harmlessly should be pursued.

NUCLEAR FUEL

Nuclear fuel provided about 10 percent of electric generation in 1976. In 1985, it is anticipated that the U.S. will have about 27 percent of its electricity coming from nuclear sources.

By the year 2000, the forecast is that nuclear will be generating about 50 percent of the nation's electric energy.

The United States is not alone in its perception of the role of nuclear power. More than three dozen nations are now committed in varying degrees to this method of producing electricity.

Newspaper and television coverage of activities of anti-nuclear groups and individuals, such as those which occurred at the Seabrook nuclear plant in New Hampshire, tend to obscure the fact that the majority of the public recognizes the need for nuclear power and the excellence of the nuclear performance record. For example, in November, 1976, the American people in several states had an opportunity to make their wishes known where nuclear generation was a specific issue on the ballot. In each case the voters decisively defeated propositions which would have effectively precluded the building of new nuclear power plants.

Public opinion polls do not make the kind of news that was created by demonstrators unlawfully occupying the Seabrook plant site. But they show much more accurately the attitude of the majority of Americans who have favored nuclear power over the years. For example,

a recent opinion survey showed that 69 percent of the American people believe that more nuclear plants should be built to generate the electricity we need.

The problem is that a small, dedicated group of people who take an anti-nuclear position have been placed in positions of significance in the Carter Administration. Whether this is part of a calculated program, or simply the contemporary version of the "old boy" network operating through the more radical environmental groups, is hard to say.

ENERGY CONSERVATION

It is in the interest of the electric utility industry, its customers and the nation as a whole to support a full commitment to energy conservation. To encourage the public's participation in this area, the Edison Electric Institute announced a National Energy Watch (NEW) program in June. the NEW program stresses these objectives:

1. *To reduce the drain on fossil fuels.*
2. *To help keep the electric utility industry's need for additional generating capacity to a minimum.*
3. *To help keep consumers' electric bills as low as possible.*

The program covers three key areas: improving the thermal integrity of the home itself; installing more efficient energy-consuming systems and appliances; and adopting better energy conservation habits in the home.

Even with the most dedicated conservation efforts, however, the energy problems will still exist.

Where electricity is concerned, for example, accumulated savings by the year 2000 might reach 20 percent of what electric output might be under historical growth patterns. But even with these savings, electricity generation will have to be three to four times the 1976 level to meet U.S. needs at the turn of the century.

But if the development of coal and nuclear power is subject to delays and conservation cannot do the job alone, what about new sources of energy? Our industry recognizes the need for developing new sources such as solar and geothermal. In solar, for example, electric utilities already have many research, development and demonstration programs underway.

But encouragement and development of solar energy should not create false hopes on the part of the public. Our most optimistic estimates indicate that solar electric generating capacity might represent about one percent of the total installed capacity by the year 2000.

Despite accelerated research and development efforts in alternate energy forms, sources other than fossil and nuclear fuels will be supplying only about 10 percent of electric generation by the year 2000 — and more than half of that will be hydroelectric.

ELECTRICITY IS ESSENTIAL IN ALL SECTORS

There is an increasing realization on the part of the public that electricity is essential to provide jobs and economic progress; but, perhaps, there has been insufficient emphasis on the role electricity plays in the over-all functioning and well-being of our society as a whole. For example, without electrically driven pumps, how would the water supply needs of the population be met? Without elevators energized by electricity, how could our great metropolitan centers exist? How would buildings taller than five or six stories be practical?

Of course, as time goes on electricity plays an ever-increasing role in the residential sector. In the home, electricity provides the energy for easing physical burdens, for entertainment, communications, home security and for the maintenance

of an optimum indoor climate. Ten years ago, electricity's share of the new single-family home heating market was about 20 percent. The latest data for the year 1976 show that 48 percent of new single-family homes were electrically heated. Including new multi-family buildings for which the electric percentage was 59 percent, the weighted average for both types was 51 percent with electric heat.

Largely unrecognized is the importance of electricity in making it possible for a relatively small proportion of our population to feed Americans and ease the food problems of much of the rest of the world. Electricity has been basic to the continuing automation of such processes as egg and milk production, chicken brooding, and pig raising. Irrigation, crop drying, materials handling, and environmental control are among the many areas in which electricity has helped the farmer immeasurably.

Getting food from the farm to the table involves a series of complex, interrelated activities requiring electric energy almost every step of the way,

from food processing and packaging to wholesaling and retailing. Efficiency, productivity, and a food supply which is the envy of the rest of the world have been the result of the application of electric energy in agribusiness.

In industry and commerce electricity again plays a major role. Changeovers in electricity are happening everywhere, from McDonald's hamburger stands to automobile manufacturers and steel and glass makers. Merely to catalogue the uses would require a document the size of a telephone book. In just one area, the use of electric processes, the list would run from A to Z — from acid heating to zinc plating.

Electricity plays an ever-increasing role in transportation as well. The electric car is gaining more and more attention, promoted by governmental interest in funding research and development. Even General Motors has an electric car in its future. GM's president was recently quoted as saying: "Our first electric car may not be ready to help us meet 27.5 miles per gallon in 1985, but I'm hopeful that it might be widely used by the late 1980's to make its energy impact felt." The U.S. Postal Service has 382 Jeep "Electrucks" delivering mail in various parts of the country. Other possibilities for electrified vehicles are numerous. Of course, mass transit can reduce the dependence on automobiles, conserve fuel and help improve environmental quality.

Spokesmen for the Energy Research and Development Administration are projecting an all-electric transportation economy "to get the transportation industry off its petroleum base." Last year an ERDA official was reported as saying "an almost total switch to electric cars and delivery vans by the year 2000 will be the result of a need to conserve petroleum".

CONCLUSION

There is no question that the electric industry and our nation are at a crossroads in the future of energy. If our options are foreclosed, if industry's ability to supply electricity continues to face nearly insurmountable obstacles, there will most certainly be widespread shortages of electrical energy. But with dedicated effort by industry, by government and by the public, this country can have an ample supply of energy today, tomorrow and for centuries to come.

REFLECTIONS ON AN ENERGY EDUCATION VENTURE: COLORADO'S ADULT ENERGY EDUCATION PROJECT

Harold M. Anderson

Dr. Harold M. Anderson is Professor of Science Education at the University of Colorado, Boulder, and is a past-Director of the Colorado Adult Energy Education Project, a program funded by U.S.O.E.

Nationally, citizen concern about energy problems seems to be lower than at any time since the oil embargo of 1973. Never has the need for a strong popular demand for an energy policy been greater. The sense of urgency has affected the President, the Congress, utility companies and portions of the press. Yet the common man on the street seems apathetic — until someone proposes to raise the price of energy or deprive him of its benefits.

Consider the consumption of energy in the critical area of petroleum. According to Eaton, the United States imported 13% of its oil in 1973.[1] In the first half of 1977, the U.S. consumed a record average of 18.6 million barrels of oil per day, with 8.8 millions of these imported. Thus, during that period we imported over 47% of our oil.[2] Imports during this period were 31% greater than in the comparable period of 1976. At the present price of $14.60 per gallon, oil is a major contributor to our negative balance of trade (estimated to be 25-30 billion dollars in 1977).

In this paper the author reviews and reflects on a University of Colorado project[3] conceived during the fall of 1975, funded in May, 1976 and completed in June, 1977. After presenting a resume of the project, separate sections will analyze and present reflections on the goals, planning, procedures and outcomes. Finally, a summary section will focus the benefits derived from the project, and implications of the venture for energy education and action.

Project Resume

The major purpose of the project was to develop a self-supporting, exportable model of adult education designed to effectively teach people in their local communities about energy needs, alternative energy sources, public policy and conservation practice. Essential to such a program are awareness of usage, needs and related economic effects of over-consumption, the pros and cons of alternative sources, present policies (or lack thereof) and effective conservation activities. In planning to achieve our purpose the project was divided into four phases.

Phase I (May 10 - July 30, 1976) was a frantic period of preparation, planning and organization. An advisory steering committee was secured. Project descriptions and

application forms were sent to the 181 school districts in the state. Although the materials were late, twenty-five applications were received. Fifteen were assigned positions in Phase II funded by our grant. Two talented educators were selected to serve as coordinators of the project. Notices were sent to adult education agencies, Boards of Cooperative Services, State Department of Education and other institutions of higher education in the state. The Center for Life Long Learning of the University of Colorado was notified of the opportunities to use our trainees in offering credit courses for adults. In addition to using the *Alternative Energy Sources — A New Beginning* films developed at Continuing Education, five additional one-half hour T.V. programs were prepared for use in Phase III (September, 1976 - June, 1977).[4] Materials for use in Phase II were ordered, local housing arrangements and other logistical preparations were made for the future of the project.

In addition to the adult education project, the U.S.O.E. grant required preparation of teaching materials, including converting some films to film strip format and the revision of the nuclear film. Much preparatory time was spent designing the research and evaluation activities and instrumentation.

An intensive instructional and planning workshop (Phase II) was conducted for the 16 science and social studies teachers who were to serve as the teaching cadre in Phase III. During the period (August 2 - August 13, 1976) the teachers were involved from 8:00 a.m. to 5:00 p.m. in lectures by experts, a thorough study of the films to be televised and guides for their implementation, examination and evaluation of currently available materials on energy resources and conservation, study of textbooks, experiences with available simulation games, developing region-specific course outlines and organizing plans for evaluation of achievement by adults in community classes. Field trips to nuclear installations, electrical generating plants, solar homes and solar greenhouses were taken to provide contact with reality. The workshop activities were designed to exemplify strategies and techniques available for adult teaching situations. At the end of each day activities were evaluated in terms of participant reaction.

While the seriousness of the energy dilemma was recognized and emphasized by many speakers, participants were urged to maintain a spirit of hope and optimism. Conservation is necessary to prolong the time available to develop energy alternatives through research and development.

On completion of the Phase II training sessions, the cadre was prepared for its task. A communication network had been established. The group generally expressed confidence and enthusiasm was apparent. Plans had been laid for research. All indicators predicted a highly successful project.

Directors and coordinators were stunned when a number of the proposed community programs in Phase III failed to generate sufficient enrollment to justify continuance. Of a potential 15 courses, only five were successful. Several members made repeated attempts to establish programs, but were thoroughly discouraged by community apathy. One member of the cadre utilized his preparation in offering an environmental-energy course in his high school.

Those members of the cadre that were successful in securing sufficient numbers for classes maintained their planned schedules. Class meetings were used to discuss T.V. programs and study guide material with an emphasis on the role of citizens in meeting the energy challenge. The forums developed an awareness of energy-related problems, and facilitated discussion of potential solutions and consideration of possible steps that communities can take. Considerable time was spent on individual and group measures that can conserve energy and save money. Several programs involved resource people from the community.

Several simulation experiences were utilized. One was the Energy Research and

Development Administration's (now the Department of Energy) energy-environment simulator, an analog computer designed to illustrate the depletion of our resources under differing conditions of use and through which it is possible to depict the struggle between individual and small group interests. Ohters were *Energy-X, Planet Management, The Energy-Environment Game,* and *Colorado: Problems & Promises,* all of which proved very successful in stimulating fruitful interaction and debate.

Alarmed by the large proportion of classes that failed to develop, the project directors and coordinators convened the teaching cadre in November, 1976 to search for potential causes of success or failure in attracting students. The reported situations failed to show any planning differences. In the classes that were successful, a considerable number of teachers were enrolled. The state requirements for recertification may have been the incentive. The cadre reported a general lack of interest by adults. The members of the cadre were generally supportive and suggested several alternatives, including a one-day drive-in conference on energy.

Advice was sought from the steering committee. A number of the committee members referred to polls and observations that the adult public was generally apathetic. Several commented that individuals were interested in "do it yourself" projects or systems that could save the person money. Very few would be interested in awareness objectives.

On the basis of the advice from the cadre and steering committee, a number of actions were taken. Sponsors were sought from industry and interested individuals without success. We made presentations to the hearings of the Governor's Energy Policy Council, Senator Haskell's energy hearings, several agencies and community colleges without success. Our coordinators served with the Governor's Energy Council, encouraging adult energy education at every opportunity. We considered holding an energy fair to recognize outstanding school energy projects but felt this was not fair without considerable advance notice for students. Furthermore, such a group would not be consistent with our project goal.

We did decide to hold a one-day drive-in conference with supporting sponsorship from the Metropolitan League of Women Voters. A conference was advertised for March 12. We are pleased to report that, despite a heavy spring snowstorm, over 100 individuals (primarily League of Women Voters and affiliates) attended. Of the 112 who had pre-registered, forty failed to check in. Thirty walk-ins who had heard about the conference via friends and press releases, brought the total attendance to 102. Evaluations from the participants were collected.

Phase IV (May - July, 1977) served as a period to process data, evaluate the outcomes and prepare a final report. The project did serve to provide considerable information. However, we had failed in our major objective of developing a self-supporting exportable model of energy education for adults.

Despite efforts by projects such as this, by the press, radio, television and other shapers of public opinion, the need for energy awareness remains.

Reflection Over Goals and Needs

Our population continues to live in comparative luxury, blatantly unaware or unconcerned about conditions in the rest of the world. With a population approaching 220 million in a world population of over 4 billion (less than 6%) we consume nearly 40% of the annual supply of energy. What kind of image does this portray to the world? What questions does it raise about our morality when we are gluttonous and others starve?

Perhaps the most compelling reason for effective energy education for adults relates to a highly prized constitutional principle - *the consent of the governed.* This is the principle that protects us from tyrants - from abuse by those who come into power. But like a two-edged sword, the principle may create problems at times. The power residing in

the electorate makes it difficult to discipline ourselves as a nation and practice austerity when needed. Greedy individual voters are hesitant to give up their "rights" for the common good.

In energy legislation we have a prime example. At a time when we desperately need an energy policy - Carter's, Ford's, or one from Congress - our legislators prevaricate, side-step issues and do everything except exhibit statesmanship. After all, one does not return to Washington if one offends the constituency at home. Only an informed and socially-oriented electorate can solve the problem.

As a state, Colorado has an extremely high stake in the energy decisions of our nation. Inside our borders are deposits of coal, petroleum, oil shale, uranium, natural gas and minerals that other parts of our nation wish to utilize in their search for energy. Metropolitan Denver serves as headquarters for many energy developers with operations in the neighboring states. Powerful organizations seek to exploit our energy resources.

Water, not energy, is Colorado's most pressing problem. Our population, now approching 3 million, has encroached heavily on arable land and associated water rights. Anyone questioning the seriousness of our water problems is urged to carefully read *The Desert Empire* by George Sibley.[5] Any energy development will require water that the region can ill afford. Some fuel transport systems like slurry pipelines could be disastrous. As a nation, we must realize that our energy problems are inextricably entwined with water, population, land use and economics.

Reflections on Planning and Procedures

Difficulties experienced in Phase III of the project have some implications for future planning. While conversations with many people prior to the planning stage secured support for the proposal, adult students did not appear at registration in the numbers expected. While the idea of a self-sustaining program is appealing to the author (many funded programs wither when support is gone), there must be a "continuing incentive" to the person who pays the tuition. The student becomes interested if he believes there is something that he can do with his knowledge other than vote. Can we include activities and means to move into the power structure? Can we include ideas for community action that can give a feeling of participation? Of being able to make a difference as the result of his knowledge?

Reports from potential students and our cadre indicate that unless there is some "personal" return from energy education, adults will not invest. Vocational or practical education tends to have more appeal to individuals than liberal education concerned about societal benefits. Many people are interested in how to insulate homes, construct functional solar systems, and get more efficient operation of energy sources, thereby saving money. Yet the experiences of the general population with unreliable companies and persons who must experiment with the client's situation have created considerate distrust. The public wants up-to-date, but reliable information.

If one views the positive reaction of the clientel at the one-day conference of March 12 as an omen (85% reported it as one of the best conferences they had attended), such conferences may be useful for educating the citizenry. The conference started with a penetrating yet humorous visual presentation by Professor A. A. Bartlett of the University of Colorado Physics Department on the exponential function showing the ridiculous results of continued growth, whether it be population, city size, wealth or energy consumption. Presentations of five of the Alternative Energy Films with a speaker-respondent expert in the area were duplicated so each attendee could participate in two sections. A speaker from the Governor's Energy Council gave a report on actions of that office. A panel of experts and futurists fielded questions at the concluding session. Because more such conferences are scheduled in the near future,

attempts to evaluate their impact seem desirable. If the method continues to be consistently successful, more low cost conferences should be encouraged.

Reflections on Project Outcomes

The original project design involved plans to test the relative impact of our materials and modes of presenting them in enough classes to minimize by randomization the effects of teachers and students. The failure of a number of classes to materialize forced the abandonment of that design. The findings below are based on observations and data from isolated classes and thus may reflect teacher and pupil differences among classes.

It is quite evident that adults were not willing at the time of this project to invest time and money in learning about our energy dilemma. Our data show that many consider the energy crisis of 1973 a trick contrived by oil companies to increase their profits. How can there be an oil shortage when gasoline stations have competitive pricing?

Students in the classes which met for the longest periods of time showed the greatest gains in scores on tests. We are not surprised. But it does show that the energy program we envisioned for citizens requires a minimum of 30 hours and, preferably, more time.

That high school students showed greater gains in their class than adults in most of the other classes has some significance. To educate pupils in high schools in energy problems seems quite fitting in view that they are the new generation of voters. This outcome does justify encouraging the cadre trained last year to use their preparation to teach high school pupils about energy. Furthermore, an intensive effort to prepare and encourage teachers to teach awareness and conservation of energy is feasible as well as desirable.

Project Accomplishments and Recommendations

At the completion of any project recognition of the benefits derived is important. In this case, a cadre of sixteen teachers is well prepared. The individual teachers are providing leadership in energy education throughout the state. Many will present courses related to energy in their schools. If a demand for adult courses does materialize, these teachers are ready to serve.

The classes that were taught have served to inform a portion of the public. We believe many of these persons will continue to inform themselves on issues via the communications media. Such informed individuals are useful in informing others.

Our March conference did provide a model that was highly successful in terms of participant reaction. Cooperation with the League of Women Voters proved very beneficial because of their enthusiasm, and the high regard the public has for this constructive group.

The efforts of our coordinators in working with state and community agencies have been rewarding to them and us. We have found there is no central coordination of efforts or clearinghouse on proposed activities.

Our search for materials uncovered the existence of large quantities of materials related to energy problems and conservation. While the quality of materials varies greatly, a major problem seems to exist in dissemination for use. Materials prepared within the project have been an additional contribution. We believe our project was helpful in making materials known to teachers.

On the basis of our experiences with this project we recommend:

1. Encouraging the high schools to include courses on energy in their programs for all students. These students are going to be voters soon.
2. Giving all possible assistance to schools in adopting educational programs such as Energy and Man's Environment, Energy and Society, and the National Science Teachers Materials.

3. Cooperating with all community, state and national groups which seek to provide energy education for the public.
4. Conducting audience availability, as well as content needs, assessment in planning educational ventures.
5. Working cooperatively with energy producers (utility companies) in their attempts to inform the public, yet monitoring their materials to make certain that balance is achieved.
6. Practicing, as well as preaching, conservation so that our credibility with the public may be enhanced.
7. Aiding in the dissemination of teaching materials so that teachers become familiar with available, innovative strategies. Workshops which deal with dissemination need to be encouraged.
8. That efforts be made to promote concern for the economic and environmental effects of energy problems.

Persons who are concerned about the welfare of our nation need to become involved in the energy issue. If we are to survive as a nation, our voters need to be concerned with the common good, Our present action may lead to political and economic disaster if another crisis strikes.

Yet we must face the future with optimism and courage. To become unduly pessimistic is to lose our personal efficiency and public support. We will do well to recall the statement by Mesarovic and Pestel in their book, *Mankind at the Turning Point:*[6]

"Many recent analyses of the long-term prospects for mankind have produced gloomy conclusions. Promptly, they were called doomsday prophecies. Yet the rapid succession of crises which are currently engulfing the entire globe are the clearest indication that humanity is at a turning point in its historical evolution. And the way to make doomsday prophecies self-fulfilling is to ignore the obvious signs of perils that lie ahead — which indeed are already felt — and rely solely on 'faith'. Our scientifically conducted analysis of the long-term world development based on all available data points out quite clearly that such a passive course leads to disaster. It is most urgent that we do not avert our eyes from the dangers ahead, but face the challenge squarely and assess alternative paths of development in a positive and hopeful spirit. Starting early enough on a new path of development can save mankind from traumatic experiences if not from catastrophes."

Our popultion needs to concentrate on hope and not on wishful thinking. I here use hope in the sense of Thomas F. Greene,[7]

"Hope is an astonishing human capacity. It is future directed, never directed to the past; it is factual, never counter-factual. It is never wishful. It is an emotion, yet its existence requires a certain kind of world. It is neither prediction, forecast or expectation, yet it leads to all three."

In contrast, I see wishful thinking as ready to return to the past (which is impossible). While wishful thinking may involve some factual information, it frequently fantasizes. It looks to solutions of problems by others without input from one self. Often it ascribes powers to government, science or organizations — powers which are not there. It often suffers from the delusion that time and fate will solve our problems without action of any kind. It is not faith; it is a non-productive dead-end.

A sense of impotence seems to have pervaded our nation. The average citizen seems to feel that there is no constructive way that he can influence decisions in Washington, D.C., or state capitols or even in his own community. Too many see riots, strikes and violence as the means to solve problems. Temporary concessions to individuals or small groups may be won as appeasement. The underlying problems worsen. The path leads to anarchy.

In other times and places dictators and communists have taken over in times of crises. The result generally is loss of freedom, of possessions, and personal rights. Usually, there has been much suffering by the masses.

The alternative is to make participatory democracy work. This means substituting hope for wishful thinking. To see the potency of cooperative action in solving problems becomes imperative in order to overcome the sense of futility and impotence. It requires informed people who have a sense of direction and experience success in achieving goals. The faith in participatory democracy comes only through experiencing success in using it.

Energy education in the secondary schools seems to be ideally suited to restoring this faith in democracy. In a semester (or more if available) a teacher can build hope on the energy theme. There is a lot of factual information available. Separating fact from fiction will be an excellent exercise, even if very challenging. Recognition that controversies exist, even with experts, is important. Combining present facts with assessment of the future may be depressing but realistic. At these times teachers need to remind students that civilizations were successful when individuals worked together to solve problems and failed when they pursued only individual goals. Research and development progress best when the public is supportive.

Aspects of experiental education can be tied into energy programs. Projects of a local nature can be chosen where class ideas can be tested. School energy conservation can be practiced. For example, a temperature reduction in the school passed through the student council would mean some discomfort to all, but yet be for the common good. The process of succeeding at the school council level can be extended to the city or community level on other projects. Other affective learnings can be better achieved by simulation.

The secondary level appears to be the most promising for successfully reaching objectives I have presented. The schools are there, time is available and the pupils can be motivated. Both the experiential and factual learnings reinforce each other to provide a degree of performance. Efforts to educate adults should not be abandoned, but the secondary school provides an opportunity that must be utilized.

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Curricula-Enrichment Materials

WHAT'S NEW IN ENERGY EDUCATION? ENERGY & MAN'S ENVIRONMENT

John Jones

Dr. John Jones is President of Energy and Man's Environment, Portland, Oregon, a former teacher and school administrator.

Case History/Corporate Overview

Energy & Man's Environment (EME) is one of the nation's leading energy and energy conservation education programs. EME offers a comprehensive program of teacher development services and unique classroom resources, each designed to accomplish the goal of energy literacy through objective instruction.

Background

Energy & Man's Environment was initiated in 1972 as a curriculum development activity of the Public Power Council and the Washington State Department of Public Instruction. The initial purpose was to prepare a resource guide to help teachers manage energy and related environmental issues.

The first curriculum project was begun in August, 1972. The writing team included classroom teachers, university professors, industry specialists and curriculum experts. This multidisciplinary team drafted a teachers *Activity Guide*. The *Guide* provided a conceptual framework and ideas for energy education in grades K-12. This successful effort between industry, education, and government established the principle of cooperation that remains a hallmark of all EME programs.

A major change in the scope of Energy & Man's Environment occurred in February, 1973, when the Northwest Electric Light & Power Association joined the Public Power Council in providing financial and professional program support. The additional resources expanded the range of the EME educational services, and extended the service region to include the states of Washington, Oregon, Idaho, Montana, Wyoming and Utah. The Rocky Mountain Electric League obtained membership in the consortium in 1976, resulting in services to the state of Colorado. Nevada became a fully participating member in 1977. Other less formal relationships exist throughout the United States and Canada.

Positive educator response and requests for services led to the employment of a project director in August, 1973. Energy & Man's Environment was established as an independent organization and achieved the status of a nonprofit corporation in January, 1974.

Organization

The EME organization is designed to encourage participation by all groups and individuals with skills, interest, and resources to contribute to a balanced and objective energy and energy conservation education program.

A Board of Directors, composed of educators and representatives from sponsoring

groups, establishes corporate policy. Policy implementation and general administration is the responsibility of the President, an experienced public school and university teacher and administrator. Support to the field staff is provided by the Program Director, an outstanding teacher and curriculum specialist.

Delivery of educational services is the direct responsibility of the State Coordinators. Each Coordinator is a highly respected educator selected from among the leadership of his/her state. Supporting each Coordinator is a State Planning and Implementation Committee. Like the Coordinators, Committee members are selected on the basis of their demonstrated teaching excellence, academic integrity, and experience in program planning and implementation.

State Planning and Implementation Committees vary in number according to state population and geography. Committees typically include members from state government and resources management agencies, universities, state education agencies and industry, as well as the public schools. Emphasis is placed on the creation of unique state organizations which serve the special energy education needs of their educator colleagues.

Professional Development Programs

Energy & Man's Environment offers a unique approach to energy education. Each EME instructional program is "custom tailored" to meet the special needs and interests of the individual audience. This essential planning process is a responsibility of the EME State Coordinators and State Planning and Implementation Committees.

Program Development

An interrelated, two-part development plan was initiated in January, 1974. The first component, the Regional Teacher Development Program, is designed to accomplish two specific objectives: (1) to create awareness of the nature and scope of the energy dilemma and its educational implications, and (2) to encourage and support the infusion of balanced and objective energy materials into school curricula. These objectives are being accomplished through three mutually interdependent phases.

Phase One of the Regional Teacher Development Program emphasizes energy awareness through state-wide conferences. Conference programs emphasize careful examination of the world, national, and regional energy situation; analysis of energy options; interaction with energy specialists; identification of instructional resources; and preparation for Phase Two implementation activities.

Phase Two of the Regional Teacher Development Program consists of school district workshops. Workshops emphasize: (1) Examination of the energy situation, (2) Systematic introduction and examination of instructional resources, (3) Preparation of original teaching materials, (4) Practice at using educational materials, and (5) Planning for classroom implementation.

Phase Three includes content-focused seminars and special programs. Seminars offer continuing support and assistance to educators who have participated in orientation conferences and implementation workshops. Special programs are designed and conducted for other groups.

The EME staff brings a thorough knowledge of program planning and available resources to the individual programming opportunity. However, all program planning efforts are undertaken as a *COOPERATIVE RESPONSIBILITY* of the EME staff and local education agency for whom the program is being developed. In this way, EME insures the appropriateness of the resulting program and encourages "ownership" on the part of the educational agency.

Instructional Resources

The second principal EME component is the Curriculum Development Program. This ongoing effort is designed to produce original instructional and reference

resources for energy and energy conservation education in grades K-12.

All EME materials are teacher-made and based on a multidisciplinary conceptual framework which reflects both knowledge of the teaching-learning process and the practical needs of the classroom teacher.

The first EME product was the *Activity Guide*, a rich source of ideas for teaching energy concepts. Revision of the *Guide* became the first objective of the Materials Development Program and was accomplished during the fall of 1973. The resulting seven-part *Activity Guide* serves as a basic reference source for energy and conservation education concepts, objectives and classroom activities.

In January, 1974, EME initiated a second major curriculum development project. Assisted by several state education agencies, EME selected and contracted six outstanding regional school districts to draft teaching units for classroom use. The three-year development sequence of classroom testing, editing and production involved more than 150 education and energy specialists from throughout the Western United States. The result is *Energy and Conservation Education: Activities for the Classroom*, a four-volume set of 250 teacher-developed and classroom-tested lesson plans which provide a variety of multidisciplinary resources for teachers in grades 1-12.

In addition to its teaching materials, EME has created several reference documents designed to facilitate independent materials preparation. These documents include an *Energy & Environment Glossary*, *Energy Education Bibliography of Key Instructional Resources*, and an *Energy Films Index*. These and other instructional resources are intended to make the teacher's participation in the EME Regional Teacher Development Program a rich and rewarding experience.

Summary

EME encourages active participation by all groups interested in balanced and objective energy education. The corporation offers a unique educational program designed specifically to meet the critical need for an energy literate public.

National Science Teachers Association

NSTA'S ENERGY EDUCATION PROGRAM

John Fowler

Dr. John M. Fowler is Director of Special Projects for the National Science Teachers Association, Washington, D.C. and author of several energy/environment books and articles.

The National Science Teachers Association (NSTA) for some years has encouraged the use of environmental topics as vehicles for science education. Energy topics, which combine natural and social science are, of course, ideal for such purposes. The upsurge of governmental interest in energy education which followed the oil embargo of Fall/Winter 73-74 resulted in an opportunity to develop a major program.

The first NSTA materials development effort in energy education began in July 1974 with support from the U.S. Office of Environmental Education. The *Energy-Environment Source Book*, *Energy-Environment Materials Guide*, and the *Energy-Environment Mini-Unit Guide* were the result of this contract. We subsequently received a contract from the Federal Energy Administration, which allowed us to distribute free of charge, 15,000 sets of these to science and social studies department heads and chairpersons. Since the end of the free distribution, an additional 4,000+ sets have been sold by NSTA. The *Source Book*, in particular, is almost sold out.*

It was clear to us from the beginning that teacher background materials would not be sufficient to cause any major introduction of energy into the K-12 curriculum. What was needed was classroom materials.

Early in 1976 we received the first of a series of contracts with the Energy Research and Development Administration (ERDA) and entered into the "Project for an Energy-Enriched Curriculum" (PEEC). The major products of this ongoing effort have been fifteen interdisciplinary classroom units on energy-related topics, nineteen *Fact Sheets on Alternate Energy Technologies*, and a series of workshops, journal articles, and public presentations.

The NSTA materials are being printed and distributed free of charge by the U.S. Department of Energy. The instructional packets, six in final form and nine in draft form, are briefly described in this article. We encourage teachers not only to request and use them, but also to let us know their reactions to them.

We also encourage teachers to make basic input into the PEEC philosophy and, for that reason, describe below the goals and assumptions guiding that program.

Goals and Assumptions

We have proceded from three basic assumptions: that the energy/environment/economic (E/E/E) problems are real; that they are long lasting; and that their solution is probably the most important challenge facing this country over the next decade or so. If these assumptions are accepted, then it follows that space and time must be set aside in the K-12 curriculum for E/E/E topics.

* We hope to announce in a later issue of *Energy & Education* plans to revise this popular resource.

The three major goals that give us guidance are the following:

1. Our student citizens will have to deal with political, social, and economic decisions on E/E/E issues. It is a duty and challenge for educators to prepare students for these decisions;
2. Many students will find careers in energy industries or careers in industries which will depend crucially on energy decisions. Educators are responsible for preparing students for these careers; and
3. The energy transition years that we have entered will be accompanied by changes in life style. Students should be aware of and prepared for these changes.

In addition to these basic assumptions, there are some pedagogical assumptions that are providing strong guidance for us. The most important of these is that the E/E/E concepts and issues do not need to stand as a separate curriculum, but can, in fact, be infused into existing curricula.

We are in a sense in the process of constructing a "hidden curriculum," which we will remove from hiding in the sections that follow. We have tried to identify the most important concepts and issues in the E/E/E area. Having identified these, however, we look at existing learning goals which teachers have accepted, and ask "Where can we reach an existing learning goal through an energy example?" Thus the titles of the instructional units that we have produced so far have such names as: *Energy, Engines, and the Industrial Revolution, How a Bill Becomes a Law to Conserve Energy, U.S. Energy Policy — Which Direction?* and *Transportation and the City.*

Our evaluation, both formal and informal, tells us that our assumption that E/E/E topics can be infused into curriculum is correct, but we invite your further comment.

The Hidden Curriculum: "The Over-Arching Concepts"

We have put together, with considerable help from others, a listing that we call the "over-arching concepts in energy/environment/economics" and this listing will contain, when complete, those subjects that we feel must be a part of the students' curricular experience. With some trepidation we reveal this unfinished curricular outline. We have tried to condense this list to a bare minimum and present it here, asking that you tell us what is superfluous and what is lacking.

OVER-ARCHING CONCEPTS IN ENERGY-ENVIRONMENT-ECONOMICS EDUCATION (K-12)

1. **Energy Is**

   Energy takes various forms: heat, light (radiation), and motion are the most obvious ones. It is observed and used in the kinetic form, but usually extracted, stored, and often transported in the potential form.

2. **Energy Flows**

   All systems, physical, biological or industrial, depend for their vitality on energy flowing through them. Energy is indestructible, it is neither created nor used up. It is converted from one form to another as it flows through the process from extraction to eventual discard.

3. **Energy "Usefullness" is Finite**

   Although energy itself is non-destructible, its usefulness to any system (as food or fuel, for instance) is finite. The "usefulness" of an amount of energy decreases at each conversion and it is this finiteness that leads to concerns over efficiencies and over shortages and "running out."

4. **Energy is a Commmodity**

   Energy can be bought and sold. Its value depends on its usefulness and on other things which relate to social, political, environmental, economic and political values.

5. **Energy is Important**

   The production, transportation, and consumption of energy affects and is affected by most other processes in the system through which it flows. These tight interconnections hold whether we are considering biological systems, ecological systems, industrial systems or local, national, or global social systems.

6. **Energy Policy is Man-made**

   While certain basic energy requirements for food, warmth, transportation, and manufacture must be met in any society, the details of how these needs are met depend crucially on the values and political and economic structure of a particular social group.

Procedures

The classroom units which implement this hidden curriculum are an attempt by the PEEC staff, with help from consultants, steering committees, and teacher-writers to match these major concepts to grade level specific skills in science and social studies.

We have depended strongly on the "Eureka Effect." We have hoped, by putting the concept list and the skills before creative people, to stimulate the response: "Hey! You could create a unit on . . . "

We are thus very dependent on teachers for the final pedagogical design of the classroom units. To date, some twenty-five teachers have worked for 6-8 weeks over each of the past two summers to produce the fifteen draft units.

The six initial units which were produced during Summer 1976 were distributed to more than 15,000 teachers this past school year. They have been revised on the basis of teacher reviews and the evaluation results gained from the broad scale distribution and are now being printed for free distribution by the U.S. Department of Energy. (To obtain free copies write to: the Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830.)

These six units and their grade level targets are listed below:

The Energy We Use	Grade 1
Community Workers and the Energy They Use	Grade 2
Energy, Engines, and the Industrial Revolution	Grades 8-9
Transportation and the City	Grades 8-9
Agriculture, Energy, and Society	Grades 10-12
How a Bill Becomes a Law to Conserve Energy	Grades 9, 11, 12

We are currently readying ten more units in draft form. They are:

People, Places and Transportation	Grade 3
Energy Networks	Grade 4
The Study of Two Gulfs	Grade 6
Bringing Energy to the People: Ghana and the U.S.	Grades 6-7
The Mathematics of Energy	Grades 7-9
An Energy History of the U.S.	Grade 8
Energy in the Global Marketplace	Grade 10
The New Westward Movement	Grade 11
The U.S. Energy Policy — Which Direction	Grade 12
Energy Futures	Grade 12

We are planning to place these units in selected test schools during the 1977-78 school year. But we also encourage *any* teacher who wishes to use *any* of these draft materials

to request them from the Technical Information Center whose address is given above. These ten units will be revised and published for distribution during the 1978-79 school year.

The NSTA looks forward to two or three more years of energy materials development. We expect to produce 30-40 units in all and in this way to cover the "hidden curriculum." We do not anticipate that the job of bringing energy education into the schools will then be completed. It will have only just begun.

It is our hope that the NSTA project will show that E/E/E topics and issues can be taught successfully in the schools and that a more knowledgeable citizenry can be developed in this way. It is equally important, in our view, that we demonstrate the educational usefulness of energy as an organizing theme. We want to show that a theme with real and immediate implications for the world outside the classroom produces education that is more alive than that which has been obtained using traditional materials.

If the teachers who use and perfect the NSTA interdisciplinary materials are successful, the educational system will have contributed significantly to the solutions of some of the nation's more pressing problems. That same success, however, by necessity, will have contributed to the solutions of some of the problems of education. Those are two fat birds, and the NSTA has started to pick up the stone to fell them both. We need help from all of you to launch it. This article, in the end, is a request for that help.

Biological Sciences Curriculum Study

ENERGY AND SOCIETY: INVESTIGATIONS IN DECISION MAKING

Faith Hickman

Faith Hickman is a Staff Consultant for the Biological Sciences Curriculum Study in Boulder, Colorado, is currently serving as the Project Director for the Educational Needs Assessment Project in Human Genetics and is Coordinator of the revision of Biological Science: An Inquiry Into Life.

The Biological Sciences Curriculum Study, Boulder, Colorado, has just released a new program for energy studies. *Energy and Society: Investigations in Decision Making* is a nine-week instructional unit designed for high school, college, or adult students. The unit provides opportunities for students to acquire accurate information about energy, to identify and analyze their own attitudes and those of others, and to consider questions and concerns about energy-related issues.

During the course of the unit, students discuss basic information about energy, explore some possible consequences of energy decisions, and select an energy-related research problem that they then investigate. In the context of each student's investigation, seven categories of factors affecting energy decisions are considered. These categories are politics, economics, technology, attitudes, health and safety, environmental impact, and physical laws. Through consideration of empirical data and through examination of personal and community values, students attempt to arrive at an energy "recommendation" for their community. The issue is finally carried one step further, to the consideration of national and world energy futures.

The philosophy of the program is summarized in the following excerpt from the Instructor's Manual:

> The outcomes of education that most people consider desirable are for students to learn how to think and how to learn. Neither of these goals is accomplished when a subject is taught as a rhetoric of conclusions, or as a litany of facts. Learning how to learn requires the development of self-direction, questioning, problem solving, and decision making. Learning how to think involves the ability to acquire accurate information and, through the analysis of all available data, to arrive at the most appropriate conclusions.
>
> *Energy and Society* is designed to foster these goals of education. Its activities are selected to stimulate active inquiry and to encourage the honing of problem-solving skills that are known to be of value in making logical decisions. The student is taken to a point beyond the available data where normal reliability criteria

cannot be applied, where choices and decisions must be made, and where value criteria must be derived from sources other than science. The subject of energy has been selected as the content vehicle for the unit because issues and problems related to energy will undoubtedly occupy a high position on the political and social agenda of the future. That we must find solutions to these problems is apparent, for they touch almost every aspect of our environment and our economy. The opportunities for solving these problems rationally and creatively are there as never before.

In their work with the *Energy and Society* program, students gain experience in questioning, researching, and deciding through a series of activities.

Both the design and the intent vary from activity to activity, but certain content principles are pervasive:

Energy "comes from someplace and goes someplace." Energy may be used by people or other living things as it moves through the system, but some is always "lost."

Suppose, for example, the energy in gasoline is used in an automobile engine. Some of the energy is transformed into "useful" energy — the movement of the car. Some is also "lost" as waste heat. And when the tank is empty it must be refilled. We have no way of reusing the energy that was stored in the gasoline.

There are both advantages and disadvantages to our use of energy.

Again, using the automobile example: The car provides fast, convenient transportation — a positive, desirable effect. Air pollution from the automobile is undesirable. On a larger scale, the use of energy resources has led to both high standards of living for industrial nations and, in some cases, to high levels of environmental disruption.

Everything is affected by everything else.

How we use energy is related to many other factors, such as money, politics, environmental quality, and health. Because of these interrelationships, as one writer put it, "You can't do just one thing." If one factor is changed, other factors may change as a result.

Supplies of fossil fuels will eventually run out.

No matter how much or how little we use, we are bound to run out someday. There are fixed amounts of coal, oil, and natural gas on planet Earth. Once they are all used, there will be none left.

Everything has a "price."

Nothing is free. We may pay a monetary price for some things, such as our bill from the utility company. For other benefits, the price may not be so obvious, but it will be there nevertheless. For example, what *nonmonetary* prices do we pay for hydroelectric, fossil fuel, or nuclear power plants?

The products of technology offer many avenues for solving energy problems, but technology cannot do it all.

New inventions and procedures can certainly do a great deal to help solve energy

problems. Such advances as the mass production of inexpensive solar cells could, for example, reduce our drain on fossil fuels significantly. But technology cannot serve as a magic solution to all problems. Making sound energy decisions requires the careful analysis of many kinds of knowledge.

Every person makes important energy decisions.

All energy decisions, whether large or small, should be made carefully on the basis of the best information available.

Energy and Society is available from the Hubbard Scientific Company, P.O. Box 104, Northbrook, Illinois 60062. The following materials are required for implementation of the unit:

Student's Handbook. The Student's Handbook serves as a basic resource for all the program's activities. The book includes summaries of each activity and provides background information to assist students in designing and conducting investigations of energy questions. The handbook is *not* a text. The content chapters serve as introductions to discipline areas that must be considered when energy decisions are made.

Instructor's Manual. The Instructor's Manual includes objectives, instructional strategies, suggestions for evaluation, and other information necessary for initiating and implementing the unit.

Man and the Biosphere: Energy Uses and Reserves, a set of Daylight Blackboard Projection Slides, provides for discussion of basic information on energy reserves and uses in the United States.

Energy: Back to the Source film loop (silent, Super 8 mm). Appropriate for use as an introduction to the "tracing direct and indirect energy uses" activity. (Optional)

Alternative Energy Sources card set. Seven color photograph cards with directions for investigation and discussion.

Energy Management Game. The energy game is a management simulation that focuses on the ramifications of energy use and energy needs in a community.

ENERGIZING YOUR CURRICULA
— energy ideas/activities/projects for classroom implementation

MODELING EXPONENTIAL GROWTH!

John Christensen

John Christensen is an environmental educator in Cherry Creek Schools, Colorado, a consultant for the National Science Teachers Association and co-author of a forthcoming book dealing with energy and energy education from which this activity was borrowed. It has been edited with permission of the author.

Background:

Probably the most significant cause of the energy/environmental predicament is the phenomenon of exponential growth. Over the past few decades, population, non-renewable resource consumption, food production, industrial output and pollution generation have all been increasing exponentially. To understand the energy and environmental crises, one must understand exponential growth. This activity is designed to give that understanding. It is built around the population problem, but can be applied to automobile production and disposal, electrical generating plant construction and demolition, etc.

Purposes:

1. To use dice to model exponential growth.
2. To change the variables and attempt to slow down and halt exponential growth.

Procedure:

In this activity you will use dice or colored wooden cubes to model population growth. Each die or cube represents a person. Each throw represents a year. The directions are written assuming you are using dice. If you use wooden cubes, make the substitutions shown below.

event	dice	cubes
birth	3 or 6	white, red
death	1	black

A "3" or a "6" represents the birth of a child, so each time one of them comes up, add a die to the population. If a "1" comes up, a death has occurred, so remove it from the population. Hence you are modeling a situation where the birth rate is twice the death rate. You also have a population growth rate of 1/6 or about 17%.

PART A: *Unrestricted Exponential Growth (UEG)*

Put 6 ordinary dice into a container (Adam, Eve, Cain, Abel, Sally, and Alice). Shake the container and dump the contents out onto a smooth, hard floor. Remove and count all the 1's that appear. Record the number of deaths on the chart for Part A. Count up all the 3's and 6's that appear. Since they correspond to births, add a die for each of them. Then fill in the required information in Chart A. Repeat this procedure until the total population exceeds 500 people.

PART B: *The Effect of Instituting a Limited Birth Control Program (LBC):*

Return to the year where your population first exceeded 100 people. Place that many dice into the container; but now introduce a limited birth control program. This will be modeled by having a "3" and every other "6" represent a birth. The remaining half of the 6's represent women who are on birth control, so a birth has been prevented. If an odd number of 6's comes up, round-off in favor of a birth half of the time, and in favor of a prevented birth for the other half of the cases. Model this situation from where you start to the year 30, using Chart B. You have essentially cut the population growth rate from 17% to 8%.

PART C: *The Zero Population Growth Plan (ZPG):*

Again return to the year where your population first exceeded 100 people. Place that many dice into the container. But now introduce a large scale birth control program. This will be modeled by having *all* the 6's represent women using effective birth control techniques or women married to men using effective birth control techniques. Hence, a "1" represents a death, a "3" represents a birth, and a "6" represents a prevented birth. Model this situation from where you start to the year 30, using Chart C.

PART D: *World Population Trends:*

The following is a listing of estimates of world population (in millions), 1650 to 1976. Figures such as these are compiled by the United Nations and are published in most almanacs.

Population Estimates (millions)	
1650 = 470	1940 = 2,295
1750 = 694	1950 = 2,517
1850 = 1,091	1960 = 3,003
1900 = 1,571	1970 = 3,632
1930 = 2,070	1976 = 4,100 (est.)

Plot a graph of world population *vs.* time (1650 to 1976).

PART E: *The Nature of Exponential Growth:*

Examine the following four facts about exponential growth and relate them to your graphs.

1. Exponential growth occurs whenever the rate of growth is directly proportional to the quantity of material present.

$$\frac{\Delta N}{\Delta t} \propto N$$

2. A quantity exhibits exponential growth when it increases by a constant percentage of the whole in a constant time period (like compound interest on a savings account).

$$\frac{\Delta N}{N} \propto \Delta t$$

3. Exponential growth is deceptive, because it starts out very slowly, but it is capable of generating immense numbers very quickly.
4. It is useful to think of exponential growth in terms of *doubling time*.

$$\text{Doubling Time (in years)} \simeq \frac{70}{\%\ \text{annual growth rate}}$$

The Characteristics of the Exponential Generation (1974):

Quantity	Annual Growth Rate	Doubling Time (in years)
World Human Population	2.1 %	33
World Oil & Gas Consumption	7 %	10
World Industrial Output	7 %	10
World Food Production	1 %	70
Electric power gen. (U.S.)	9.25%	7.6

Data:

Chart A: *Unrestricted Exponential Growth (UEG)*

Throw No. (Year)	Number of Births (Nb)	Number of Deaths (Nd)	Number of Dice (population)	Population Growth Rate $\frac{\Delta N}{\Delta t} = \frac{Nb - Nd}{1}$ = people / year
0	—	—	6	—
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Throw No. (Year)	Number of Births (Nb)	Number of Deaths (Nd)	Number of Dice (population)	Population Growth Rate $\frac{\Delta N}{\Delta t} = \frac{Nb-Nd}{1} = \frac{\text{people}}{\text{year}}$
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				

Data:

Chart B: *The Effect of Instituting a Limited Birth Control Program (LBC)*

Throw No. (year)	Number of Births (Nb)	Number of Deaths (Nd)	Number of Dice (population)	Population Growth Rate $\frac{\Delta N}{\Delta t} = \frac{Nb - Nd}{1} = \frac{\text{people}}{\text{year}}$
—				
—				
—				
—				
—				
—				
—				
25				
26				
27				
28				
29				
30				

Data:
Chart C: *The Zero Population Growth Plan (ZPG)*

Throw No. (year)	Number of Births (Nb)	Number of Deaths Nd)	Number of Dice (population)	Population Growth Rate $\frac{\Delta N}{\Delta t} = \frac{Nb - Nd}{1} = \frac{\text{people}}{\text{year}}$
—				
—				
—				
—				
—				
—				
—				
25				
26				
27				
28				
29				
30				

Graphs:
PART A: *Unrestricted Exponential Growth (UEG):*
Use your data to plot graphs of:
1. Population vs. Time (years)
   a. plot first on ordinary paper.
   b. plot again on semi-log paper.
2. Population Growth Rate vs. Time (years)
3. Population Growth Rate vs. Population

Note: If you are confused about which graphs to plot, see the graphing summary at the end of this section.

PART B: *The Effect of Instituting a Limited Birth Control Program (LBC):*
Use your new data to plot graphs of:
1. Population vs. Time, beginning LBC to year 30 (ordinary graph)
2. Population vs. Time, beginning of LBC to year 30 (semi-log graph)

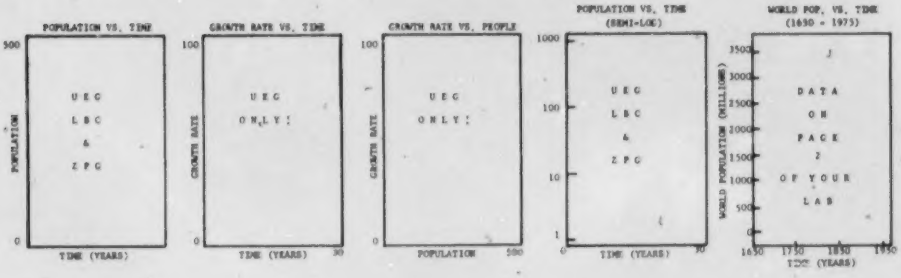
Plot these on the same graphs as in Part A, but use a different color.

PART C: *The Zero Population Growth Plan (ZPG):*
Use your data to plot graphs of:
1. Population vs. Time, beginning of ZPG to year 30 (ordinary graph)
2. Population vs. Time, beginning of ZPG to year 30 (semi-log graph)

Plot these on the same graphs as in Part A, but use a different color.

PART D: *World Population Trends:*
Plot a graph of world population vs. time (1650 to 1976).

The following is a summary of the graphs that are to be plotted for this lab:



Where: UEG = unrestricted exponential growth
LBC = limited birth control
ZPG = zero-population growth
Write one conclusion for each graph. Write it on the graph!

Teacher's Guide
Modeling Exponential Growth

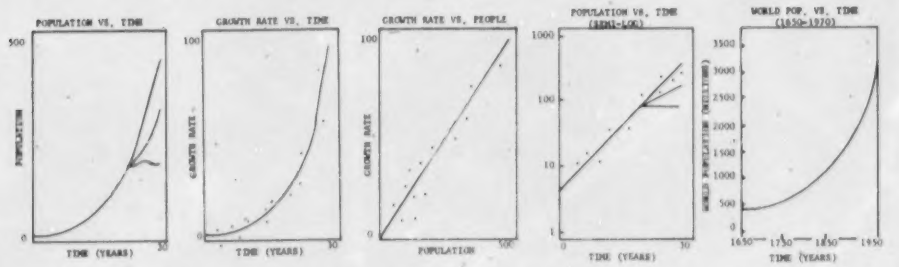
Discussion of Activity:

There is a connection between exponential growth and all of our energy/environmental crises. This activity should precede all discussion of exponential growth, population, consumption patterns and pollution generation.

In Part A, it takes about 20-25 minutes to build the population from 6 to 100 and only about 5 minutes to build it from 100 to 500, an important observation of quantities growing exponentially.

Expected Results:

The sketches below represent typical results:



One problem some students have is with drawing the best line or smooth curve through their data in the case of Growth Rate vs. Time and Growth Rate vs. Population. A graphing review prior to this activity may be helpful.

If time permits, have some students plot a World Population vs. Time graph on semi-log paper, or at least show a plot of this in class. This will help answer the question — Is the rate of world population increase declining?

Often one group in forty will start with so many deaths in their first few throws that their population never does increase. You may want to use their data as an example of a plague. If you don't wish to take the time to make this point, have the group begin again.

Sample Conclusions:

1. Population vs. Time

   When population grows exponentially and unchecked, it grows slowly when the population is small and then rapidly increases once a significant population base is established.

   The limited birth control program slows the overall growth; but since it is still exponential, it can get out of hand if given enough time.

   Only when the birth rate equals the death rate is the population growth checked.

2. Growth Rate vs. Time

   As the population increases, so does the growth rate. It appears that the growth rate also increases exponentially with time.

3. Growth Rate vs. Population

   Averaging out the randomness which is very pronounced when one deals with small numbers of objects, one can see that the best graph is a straight line which passes through the origin.

   $$\text{Hence: Growth Rate} \propto \text{Population}$$

4. Exponential growth is indicated by a straight line on semi-log paper. This can serve as a test for exponential growth.

   The limited birth control program reduces growth, but the growth is still exponential.

   The ZPG plan stops exponential growth.

5. World Population vs. Time (1650 - 1976).

   This graph looks very similar to the one obtained for unrestricted exponential growth. World population increases slowly from 1650 to 1900, when technology and medicine were relatively undeveloped. However, after 1900, the curve shoots up rapidly. Now, world population increases more in a few decades than it did in a few centuries before 1900.

Discussion:

Discuss the graphs and the conclusions for each one. What you do from there depends upon your class, your priorities and the attitudes prevalent in your area. It is easy to say that exponential growth can be stopped by equating the birth rate to the death rate. How this is actually accomplished is another story altogether.

Materials:

You will need three-cycle semi-log paper. This can either be purchased or crudely drawn out and duplicated. (Use the K scale of a slide rule for making out the log scale and a ruler for making out the linear scale.)

The activity is best accomplished in groups of 6 to 8 students gathered around a table. Dividing up the labor saves a great deal of time and is a great exercise in group cooperation.

Provide each table with a large can of 300 dice (or cubes). When the population grows beyond that, either roll twice or double your results. Most choose to double their results. For a class of 30 students, use 4 groups. Hence you need 1200 dice. Purchase 1400 to make up for losses and petty thievery.

Dice may be purchased at most variety stores. Painted wooden cubes work just as well and have several advantages over the dice:

1. They cost less (about 1/10 as much).
2. Colors can be separated faster than numbers.
3. They are less likely to be stolen — especially if they are only painted on three sides.
4. It probably takes less time to make 1400 cubes than to find a source of dice, get permission to buy, fill out forms, and wait for the dice to arrive.

Cut the dice from either ¾" birch or maple — they soak up less paint and don't easily chip. From a board ¾" x 2 ft. x 7.5 ft. you can cut approximately 1400 dice (allowing for the width of the table saw blade).

Before cutting, spray paint the board red on one side and black on the other. Then cut your cubes. Place all the cubes on a large sheet of paper unpainted side up and close together (no spaces between the cubes). Spray paint a third side white.

Easy Calorimetry

WHERE HAVE ALL THE CALORIES GONE?

Mark Terry and Paul Witt

Adapted from "Hot Flashes", ENERGY AND ORDER by Mark Terry and Paul Witt with permission of the publisher, Friends of the Earth, San Francisco, CA.

Objective

To measure the caloric value of the heat that is absorbed by water from an electric hot plate, the caloric value of the electricity used by the hot plate (at point of use) and to compare the two.

Procedure

Place a known volume of water at room temperature in a heatable container on an electric hot plate. Place a thermometer in the water, turn on the hot plate, and record the water temperature every minute for six minutes (one tenth of an hour).

Have students plot a graph of temperature as a function of time.

The calculations for caloric values are simple if you've stayed within the metric system, a bit longer if you've strayed:

1. Subtract room temperature from ending temperature (in degrees Centigrade) and multiply by the volume of water used (in milliliters) to obtain the heat energy absorbed by the water (in calories).
2. Multiply the power rating of the hot plate (in watts) by the time of operation (in hours) to obtain the energy input in watt-hours.
3. Multiply the energy input by the conversion factor 860 calories/watt-hour to obtain the total input heat energy used in operation of the hot plate (calories).
4. The energy absorbed by the water (in calories) should then be divided by the hot plate input energy (in calories), and the quotient multiplied by 100 to give a per cent efficiency-of-operation rating.

Discussion:

There remains the question of the whereabouts of the calories not absorbed by the water. Also, if the thermometer can be left in the water through the remainder of the period, the calories lost by the water to the room can be calculated based on the decrease in water temperature. Now, where have all the calories gone?

FLUORESCENT VS. INCANDESCENT LIGHTING

University of Tennessee/ERDA

This activity has been adapted from ENERGY CONSERVATION IN THE HOME — AN ENERGY EDUCATION/CONSERVATION CURRICULUM GUIDE FOR HOME ECONOMICS TEACHERS, prepared for the Energy Research & Development Administration by the University of Tennessee Environment Center and the College of Home Economics in Knoxville. For a copy write to: Chief of Educational Programs Branch, Office of Public Affairs, Department of Energy, Washington, D.C. 20545.

Objective: To demonstrate the relative energy efficiency of fluorescent and incandescent lighting.

"WATTAGE" is not a measure of the amount of light radiated by a light bulb, instead it indicates how much power (energy/time) is required to operate it. The AMOUNT OF LIGHT a bulb or tube provides is measured in LUMENS, this number usually indicated on the bulb package. Using bulb/tube packages, compare several incandescent and fluorescent bulbs for efficiency (LUMENS PER WATT).

For example: A 100-watt incandescent bulb may yield 1750 lumens, giving the bulb an efficiency of _____ lumens per watt.

1750 lumens/100 watts = 17.5 lumens/watt

Determine the efficiency of the following bulbs, plus any others you may have:

A. 100 watt fluorescent bulb: _____ lumens/100 watts = _____ lumens/watt
B. 40 watt fluorescent bulb: _____ lumens/ 40 watts = _____ lumens/watt
C. 100 watt incandescent bulb: _____ lumens/100 watts = _____ lumens/watt
D. 25 watt incandescent bulb: _____ lumens/ 25 watts = _____ lumens/watt

1. Which type of lighting appears more efficient, incandescent or fluorescent?
2. Is it more efficient to buy four 25-watt or one 100-watt incandescent bulbs?
3. Using the bulb costs stamped on the packages, determine the cost per lumen of A-D.

Suggestions:

1. Ask the school maintenance suprvisor for empty fluorescent bulb packages. The information you need is on the package — not the bulb.
2. Have students bring in bulb boxes from home.
3. Check at home for the use of multiple low-wattage bulbs where a larger wattage bulb might be used to save energy. But remember, a larger wattage bulb gets hotter during operation and some fixtures are not designed for them.

HEAT ABSORBED BY A CLOSED AUTOMOBILE

Thomas W. Norton, et al

This activity is reprinted with permission from SOLAR ENERGY EXPERIMENTS FOR HIGH SCHOOL AND COLLEGE STUDENTS by Thomas W. Norton, Donald C. Hunter and Roger J. Cheng; Copyright © 1977 by Rodale Press, Inc., Emmanus, PA. The book is available for $5.95 from the publisher.

Objective

To measure the amount of heat absorbed by the air inside a closed auto left out in the sun.

Introduction

When a body absorbs heat and gets hot, its temperature increases. As the temperature of a body increases, the amount of energy it radiates outward also increases. You feel the effects of this when you turn on an incandescent light and the heated filament radiates its heat and light. The temperature of a body will continue to increase until a balance is reached between the rate of incoming energy and the rate of outgoing energy. Under these conditions we say that thermal equilibrium has been achieved. By measuring the temperature increase of the air inside a closed auto left in the sun, you can follow this energy flow quite easily and determine its amount.

When the sun's rays strike the auto, a great deal of absorption by the metal exterior occurs. The amount will depend in part upon the color and texture of the surface, with rough black surfaces absorbing much more energy than smooth white ones. Most of the rays that pass through the windows are absorbed by the interior parts. Heating of those parts not directly in line with the sun's rays occurs by conduction, convection, and reradiation from the parts heated directly. Since the air in the auto is fairly transparent to the solar rays, the air is heated to a greater extent by the reradiation from the hot parts than by the direct rays of the sun. This reradiation from the hotter materials consists mostly of the infrared rays, which are much more readily absorbed by the air than the more energetic solar rays.

The heat gained or lost by a substance depends upon three things: the amount of material (mass, or m), the kind of material (specific heat for that material, or s), and the temperature change (ΔT). It is computed from the formula $H = mxsx\Delta T$. The mass of a solid or liquid is easily measured with a platform balance. The mass of an enclosed gas could also be measured, but with greater difficulty. To determine the mass of air that becomes heated in the auto, you will determine the volume of air and compute its mass from its density. Assume a value of 1.08g/1 for the density of air. The specific heat of various materials is tabulated in physics and chemistry handbooks and is quite easy to obtain. For this experiment you may use the specific heat of air as 0.24 cal/g C°. The temperatures are, of course, measured by a thermometer and the temperature change is computed. If you have a Fahrenheit thermometer, a conversion scale to Celsius temperature is given in the Appendix.

Materials

Two thermometers, meter stick, auto, 10-x-10 graph paper.

Procedure

1. Determine the volume of air in the automobile. This will have to be approximated, but you can make simplifying assumptions and with the meter stick obtain approximate dimensions. Perhaps a station wagon would be good to start with, since its compartment is most regular in its dimensions. Assume that the air space is a regular rectangular solid. Measure the length, width, and height of the compartment with the meter stick.

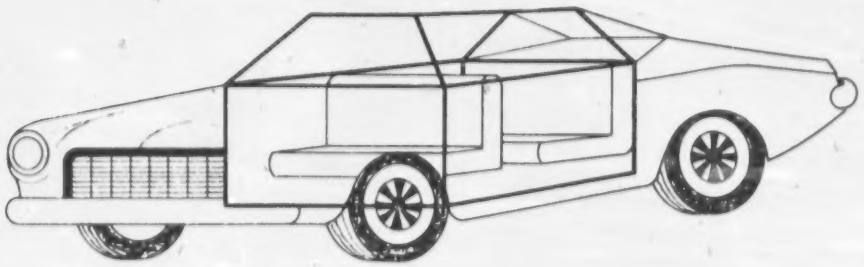


Figure 2—1

Passenger compartment volume for measuring the energy absorbed by the air inside.

2. Compute this volume from your data by multiplying length x width x height. $V = l \times w \times h$.
3. Make additions or subtractions to this volume by adding the space under the dashboard, for example, or subtracting the volume of the seats, or making other projections to refine your data.
4. Measure the initial temperature of the air in the car and expose the car to the sun. Make sure all of the windows are closed to reduce the rate at which heat is lost from the car. It is best to hang the thermometer shielded from the sun inside and not touching any solid parts. Orient it so that it may be read from the outside without your opening a door and disturbing the air inside.
5. Place the second thermometer in the shade so that the outside air temperature can be measured as well.
6. Measure the temperatures every five minutes or so to observe the short-term variations. Record the time that each observation is taken so that you will be able to determine the rate at which heat is gained or lost. Also record the sky and wind conditions so that their effects can be related to your other data.
7. Look for the highest temperature reached, the time of day it was reached, and how long it stayed there.
8. It is instructive to follow the rate at which heat is lost from the air by conduction, convection, and reradiation as the heat input of solar radiation tapers off; do so by continuing your measurements into the later part of the day.
9. Plot the temperature versus the time of day on the graph paper.

Computations

1. Determine the mass of air in the car from your volume measurement and the density value from the table in Appendix F — for example, 1.08g/l.

$$D = \frac{M}{V}$$

$$M = D \times V$$
$$= 1.08\ g/l \times V$$

If you measured the volume in m^3, change this to liters.

$$1\ m^3 = 10^3\ l.$$

Since the mass of gas also depends on temperature and pressure, perhaps you can come up with a better determination than this by using the gas laws. Note that some of the heated air is likely to leak out of the compartment.

2. Compute the maximum change in temperature that occurred by subtracting the initial temperature from the highest temperature reached.
3. Compute the heat required to raise the temperature of this amount of air from

$$\Delta H = m \times s \times \Delta T$$

You have just determined m and ΔT, and s is the specific heat of air, approximately 0.24 cal/g C°.

Note that your answer is in calories. You can convert this answer to BTU (British Thermal Unit) by

$$1\ cal = 3.97 \times 10^{-3}\ BTU \text{ or } 1\ BTU = 252\ cal.$$

To give you a feeling of how much energy this really is, compare this with the amount of heat required to bring one pint of room-temperature water to a boil.

4. Compute the rate at which solar energy was added to the air by dividing that energy by the time it took to reach the highest temperature.

$$Rate = \frac{\Delta H}{t}$$

The rate at which energy is gained or lost is called power. By referring to conversion tables, you can convert your power measurements in calories per hour or calories per minute to watts.

5. Compute the roof area (or the length times width) to find out the area over which this solar energy was received. This is, of course, another simplifying assumption. Perhaps the whole south side should be used.
6. The rate at which solar energy reaches the earth is frequently expressed in langleys per minute — one langley is equivalent to 1 cal/cm^2. As an approximation, you may use 1 langley/min as the insolation on the roof on a clear day in middle latitudes, keeping in mind that this value varies widely depending on the angle of the sun's rays and the moisture content of the air. Multiply this value by the roof area and the total time it took to reach your final temperature. This will give you the total number of calories your roof received. You could include a correction factor for the percent of cloud cover. Compare this value with the one you determined that was absorbed by the air in the car (step 3). Also keep in mind that this value does not include the energy that passed through the windows.

7. Compute the efficiency of this energy transfer from

$$\% \text{ efficiency} = \frac{\text{heat absorbed by the air (Step 3)}}{\text{heat received by the roof}} \times 100$$

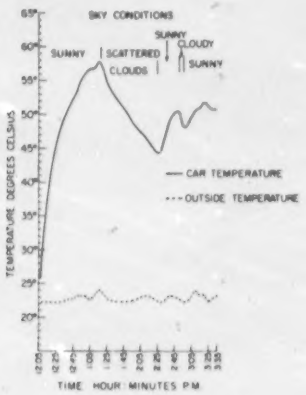
To improve the validity of this efficiency value, you will want to examine more carefully your assumptions. For example, how much glass area should be included in the collection area determination, and what was the actual insolation at the time of the measurements? Perhaps the clear-sky data supplied in the Appendix for various seasons, latitudes, and times of day could give better results. Note also the difficulties introduced by cloud cover and even wind velocity variations.

Results

Note from the determined efficiency that you have not accounted for all the energy that has been received. You can tell that it is very difficult to keep track of all of the energy — some went to heating the interior material of the car, and much of it was reradiated back to the air since the car was at a higher temperature than the surroundings; some energy was conducted and convected away; some was lost by leakage as air pressure increased.

Now that you have done this experiment, you can repeat it for different cars to see how the color of the roof or the size of the car affects the efficiency of this type of solar energy conversion. This will also tell you something about the size of an air conditioning unit that might be required for different autos. Also, compare your results when measurements are taken on calm days and windy days. It would be interesting to observe seasonal differences for the same auto, as well as what happens when the windows are left open. Figure 2—2 shows the results of one student's measurements.

In principle, all calorimetric methods for measuring solar radiation are done in this manner. The radiation is absorbed by a body, and the increase in temperature produced by the absorbed heat is measured. Try other experiments using the thermometer, thermocouple, or thermistor to measure the temperature changes. If you make a solar collector, you will want to measure its energy collection in this same way and determine its efficiency.



Temperature variations inside a closed car.
Source: Alex Pidwerbetsky, Linton High School Schenectady, New York, 1974

Discussion question

What does the graph of the temperature versus time show? Was the rate of temperature increase uniform? Did any clouds cover the sun to reduce the insolation? If so, can this be seen on your graph?

ELEMENTS OF THE GOOD LIFE WEB

Energy & Man's Environment

This activity was adapted from "Depleting Energy Sources" in the "Limits" section of the ENERGY ACTIVITY GUIDE, Energy and Man's Environment, Portland, Oregon, with permission.

Objective:

Given the opportunity to contemplate a depletion of fossil fuel reserves, the student will be able to consider its effects on other elements of a quality life.

Procedure:

You will need the following materials:

* various lengths of scrap yarn, macrame cord or string
* blank sheets of paper
* felt-tip markers or crayons

Explain to students that on April 20 1977, President Carter, in his energy address, made several references to "quality of life" What is meant by phrases such as "quality of life", "high standards of living" and "the good life"? On a chalkboard or overhead transparency write "ELEMENTS OF THE GOOD LIFE", and ask students to brainstorm those aspects — products, services, necessities — which appear to be vital to our way of life. Examples are: transportation system, food, petrochemicals, fossil fuels, communications, aesthetics, electrical appliances, housing, laws, sanitary services, industry and countless others.

Refine and consolidate items on the master list until the total equals the number of students in your class. Assign each student to play the "role" of a particular good life element, using the blank sheet of paper to make a "name tag." Make one for yourself which reads "Government."

Instruct students to stand and arrange themselves in a circle, using lengths of yarn to connect themselves to other elements of the good life on which they depend. After a few minutes, a web of interdependencies will emerge. Of course, nearly all elements are subject to governmental control and, if you are standing in the middle of the circle, you will become hopelessly entangled — much to the delight of your students.

When the completeness of the web becomes apparent, simulate a production crisis of the fossil fuels (or just oil and natural gas) by asking those students to carefully remove their strings from other elements which depend upon them. The result is a frightening simplification of the web.

Discussion

In the same way that ecosystems face potential collapse due to removal of components, so does the web of good life elements when the fossil fuels are removed. Discuss the fact that the strength of our social system which depends on many *apparently* distinct elements is maintained by diversity, weakened by simplification and almost totally dependent on the fossil fuels.

RECHARGING YOUR LIBRARY — REVIEWS/ABSTRACTS/RESOURCES

books, films, games and instructional kits for energy education

Books

Ecoscience — Population, Resources, Environment
By Paul R. Ehrlich, Anne H. Ehrlich, John P. Holdren
First-2d ed: published under title: *Population, Resources, Environment*
1050 pp. Cloth, $33.96; Paper, $19.95. W. H. Freeman & Co., 660 Market St., San Francisco, CA 94104. 1977

"Since the first edition of *Population, Resources, Environment* was published seven years ago, the population of the world has grown by almost one-half billion people — roughly the number that lived in the entire world when the Pilgrims landed on Plymouth Rock. In the same period, famine has stalked the nomads of the sub-Saharan region of Africa and the struggling peasants of the Indian subcontinent, an energy crisis has transformed perceptions of the world resource situation, and nuclear weapons have become increasingly accessible to the nations of the world. Since 1972, the world economy has been rocked by both monetary inflation and production recession. The significance of environmental deterioration has become inescapable, and its complex relation to economics has been brought to the attention of millions who had never previously paid attention to either. The realization has dawned that seemingly disparate events in the economic, environmental, and political spheres are interconnected. That civilization has entered a period of grave crisis is now doubted only by those afflicted with incurable Micawberism; everyone who is alertable is alerted."

So begins the preface in the authors' new definitive work, which continues where the first two editions stopped. Although a considerable amount of material is included from those earlier editions, an incredibly enormous amount of new information is presented in a format and with an emphasis quite different from the earlier approaches. *Ecoscience* has got to be the most authoritative, most comprehensive work dealing with ecospheric problems ever written. It is a masterpiece of easily read documentations of the multi-faceted dimensions of the human predicament.

The volume is divided into five sections: 1) Natural Processes and Human Well-Being; 2) Population and Renewable Resources; 3) Energy and Materials; 4) Understanding Environmental Disruption; 5) The Human Predicament: Finding A Way Out. It contains a separate appendix on World Demography, Food and Nutrition, Pesticides and Reproduction and Birth Control. Section 3, Energy and Materials, contains 139 pages and discusses energy resource supplies and depletion, energy use, conservation, energy perspectives, mineral stocks, substitutability and prospects for new mineral supplies. It is exceptionally well-written, richly infused with graphics, data tables and case studies and, like the entire text, is documented profusely.

Despite the rather high cost, this book is a must for the environmental educator, well worth the investment — a super reference work. — C.A.B.

Soft Energy Paths: Toward A Durable Peace
By Amory Lovins
234 pp. Paper, $6.95. Friends of the Earth International, 124 Spear Street, San Francisco, CA 94105. 1977

After his article "Energy Strategy: The Road Not Taken?" appeared in the October 1976 issue of *Foreign Affairs* and was reprinted in the mid-November issue of *Not Man Apart*, Amory B. Lovins, a staff associate of Friends of the Earth, London, was catapulted into the middle of the "soft vs. hard energy paths" controversy. Lovins' latest book addresses the problems inherent in the basic tenet of high-energy projections — that the more energy we use, the better off we are, claiming that the amount of energy consumed to accomplish our social goals could instead be considered a measure "less of our success than of our failure — just as the amount of traffic we must endure to get where we want to go is a measure not of well-being but rather of our failure to establish a rational settlement pattern".

According to Lovins, basic questions that relate to who will be requiring future energy, how much, what kind, for what purpose and for how long must be asked before we conclude that technology — any technology — is the answer ("But what was the question?"). His lucid, amply documented technical discussions deal with alternative energy technologies, logistics, economics, scale, centralization, reliabilities and nuclear proliferation.

Although quite technical in places, the book proposes refreshing alternatives to the "bigger is better" philosophy and is interspersed with Lovins' sparkling wit and analogy; e.g., the thermodynamic mis-matching of energy source to end use in our present consumptive pattern is like "cutting butter with a chainsaw". Needless to say, the author's advocacy of "soft paths" and their implications have been heavily criticized by the industry. Perhaps the best collection of critiques is contained in Edison Electric Institutes' *Electric Perspectives* (Issue Number 77/3) and readers are encouraged to review those arguments for a balanced overview of the issue. — C.A.B.

Energy Activities for the Classroom
By Herbert L. Coon and Michele Y. Alexander, editors
148 pp. Paper, $4.50. ERIC Center for Science, Mathematics, and Environmental Education, The Ohio State University, 1200 Chambers Road, Columbus, Ohio 43212. 1976

This resource book is a collection of energy education strategies culled from ideas and factual materials found in the ERIC Center for Science, Mathematics and Environmental Education. Four sections divide the book according to grade level: K-3, 4-6, 7-9 and 10-12. Each section contains numerous activities/projects appropriate for the given grade level and various disciplines. A standard format is used to describe each experience: Purpose, Level, Subject, Concept and Activity.

The major utility of this work is that it can easily serve as a reference or compendium of activities from which teachers/curriculum developers may choose those most suitable to their own unique needs, infusing them into existing instructional programs. — A.B.C.

Films

"The Bottom of the Oil Barrel"; 1974, C, 34 min., senior high-adult.
Purchase: $425. Rental: $40. Available from Time-Life Multimedia Distribution Center, 100 Eisenhower Drive, Paramus, NJ 07652.

Examines petroleum reserve estimates, depletion rates associated with each reserve and discusses projections of reserve exhaustion. The film is a good overview of the

petroleum production cycle and would be helpful in bolstering teacher background in this area.

"Challenge of the Future"; 1975, C, 29 min., junior-senior high.
Purchase: Not for sale, free loan only through U.S. Department of Energy Film Library, P.O. Box 62, Oak Ridge, TN 37830.

Views energy alternatives, including nuclear power, geothermal, solar, energy conservation and synthetics from coal and gas. Considers long-term developments of nuclear fusion, laser fusion and solar photovoltaic technologies as well as surveying dwindling fossil fuel reserves.

"Energy: Less Is More"; 1974, C, 29 min., junior high-adult.
Purchase: $230. Rental: $21. From Churchill Films, 662 N. Robertson Boulevard, Los Angeles, CA 90069.

Considers energy consumption in four end-uses: transportation, space heating/cooling, electrical appliances and waste. Details the imperative to conserve energy and trim waste.

"Energy: Critical Choices Ahead"; 1975, C, 27 min., senior high-adult.
Purchase: $175. Free loan from U.S. Department of Commerce, 1220 S.W. 3rd, Portland, OR 97207 or regional offices in your area.

An excellent film which views U.S. energy consumption, extrapolates demand to the year 2000 and examines the magnitudes and the scope of efforts needed to meet that demand by energy source. A good overview of the energy dilemma.

"Energy To Burn"; 1973, C, 20 min., elementary-senior high.
Purchase: $290. Rental: $20. Available from BFA Educational Media, 2211 Michigan Avenue, Santa Monica, CA 90404.

This addition to the BSCS Inquiry Film Library introduces through animation the relationship between population growth and energy consumption. It utilizes a format whereby the film can be interrupted at several points to facilitate classroom discussion of key questions.

"Mankind At The Turning Point"; 1976, C, 27½ min., senior high-adult.
Purchase: $210. Rental: $25. Order from Bittle Productions, Box 48, Creswell, OR 97426.

A visual report of the highlights of the Second Report to the Club of Rome. Film promotes the concept of selective growth; i.e., less industrialization in the rich countries to counterbalance more in the developing nations.

"Nuclear Dilemma"; 1974, C, 40 min., junior high-adult.
Purchase: $450. Rental: $45. From Time-Life Multimedia Distribution Center, 100 Eisenhower Drive, Paramus, NJ 07652.

Considers both sides of the nuclear fission controversy, examining potential roles of conventional light-water reactors and breeders in supplying energy to meet future demand.

"There's Coal In Them Thar Hills"; 1976, C, 20 min., senior high-adult.
Purchase: $260. Rental: $25. Available from Time-Life Multimedia (see above for address).

A documentary in which Morley Safer of CBS News interviews individuals representing all sides of the western coal strip-mining controversy. Discusses the problems involved in exploiting those reserves.

"A Thousand Suns"; 1974, C, 10 min. primary-adult.
Purchase: $140. Rental: $22.50. Order from Barr Films, 3490 E. Foothill Boulevard, Pasadena, CA 91107.

Beautiful film essay arguing for adoption of a more ecologically-oriented ethic. Depicts overconsumption, waste, depletion of energy resource reserves and reflects on our value system.

"Toast"; 1975, C, 13 min., elementary-adult.
Purchase: $180. Available from Daniel Hoffman, 909 N.E. Brazee #2, Portland, OR 97212.

Examines the energy inputs necessary to produce one slice of toast — from growing the wheat to distribution of the product to toasting. Emphasizes energy intensive aspects of agriculture. — A.B.C.

Games, Instructional Kits, Miscellaneous

"The Energy-Environment Game"; 1973 (revised 1976), junior high-adult.
Cost: $20. Available from Edison Electric Institute, 90 Park Avenue, New York, NY 10016.

This role-play simulation deals with a controversy relating to the location of a new power plant in a hypothetical region where the demand for electrical energy has surpassed supply capability. Twenty to forty students assume roles, equally divided among environmentalists, power officials, business professionals and lay citizens, as they provide input to the "Governor's Commission on Energy and the Environment". Players are exposed to numerous viewpoints and attitudes related to energy production and consumption during four to eight periods of play. The necessity of arriving at viable trade-offs between demand and environmental/socio-economical impacts is a basic theme of the simulation. Multidisciplinary in character, the E-E Game can be of special value when incorporated in traditional science/social studies lessons concerning the energy dilemma. A Teacher's Guide, thirty Player's Guides, a filmstrip and an audio cassette are included in the package.

"Energy X"; 1976, junior high-adult.
Cost: $19.50. Order from Ideal School Supply Company, 11000 S. Lavergne Avenue, Oak Lawn, Illinois 60453.

A hypothetical substance discovered in a huge meteorite, "Energy X" is an overpowering source of energy, almost totally non-polluting and extremely versatile in its end-use applications. Problem: the recovered resource is sufficient for only three years of use in only three of the eight U.S. regions chosen by the "Congressional Committee". It is the task of participants to analyze resource use, consumption and production in the U.S. today, thus establishing a rationale for the allocation of Energy X as regional representatives argue pros and cons for usage in their regions. During the simulation, students develop an awareness of the need for intelligent use of alternatives and an understanding of the relationships among the locations of major energy sources, population, regional differences and related economic conditions. An audio cassette and filmstrip, included in the kit, as well as a series of charts, tables and graphs, add authenticity.

"Colorado: Problems & Promises"; 1976, junior high-adult.
Free to Colorado schools participating in implementation workshops, free loan to schools in other states. Available through Public Service Company of Colorado, P.O. Box 840, Denver, CO 80231.

This simulation focuses on twenty-five environmental "bills", originating in and passed by the "Colorado House" and delivered to the "Colorado Senate". Students assume the roles of thirty-five hypothetical state senators, each espousing a unique environmental philosophy, background and political aspiration. The objective is to stimulate fruitful interaction and informed debate of the contemporary environmental issues confronting the State, while creating an awareness of the compromises and tradeoffs that must ultimately be considered. Among the issues: population and growth control, energy resources, energy conservation, water storage projects, predator control, wilderness reserves and fluorocarbon propellants. The simulation can be effectively utilized in science, social studies and environmental education classes and should help to motivate students to become more actively involved on their own. The simulation contains provisions for re-election, establishing lobbyist and activist groups, de-briefing and evaluation. Additionally, the simulation can be modified to reflect the legislative processes and environmental issues of other states.

"Electricity and Me — and Energy Conservation"; 1976, upper elementary-middle school.
Free loan from local utilities or Educational Services Program, Consumers Power Company, Room 867, 212 W. Michigan Avenue, Jackson, Michigan 49201.

This instructional package contains nine filmstrips dealing with the nature, generation, transmission, control and uses of electricity, plus an introductory filmstrip for the teacher and a special filmstrip on energy conservation. Nine audio cassettes are also included as well as a Teacher's Guide and duplicating masters to be used in conjunction with the filmstrips. Scripts, background information and related activities make it easy for this package to be integrated into units in science, social studies, history, economics, career education and environmental studies.

"The Energy Challenge"; 1976, Grades 5-8.
Obtained free by writing: The Energy Challenge, Box 14306, Dayton, Ohio 45414.

This booklet is part of the information/education services program of the U.S. Department of Energy and consists of two dozen duplicating masters dealing with energy: past, present and future concerns. The Teacher's Guide contains objectives, background materials, a vocabulary section and the tear-out masters. Easily infused into existing programs, "The Energy Challenge" is a worthwhile addition to your energy lesson plans. — C.A.B.

Opinionnaire

In an effort to develop an energy education periodical which meets the classroom and professional needs of a majority of K-adult educators, the editorial staff enthusiastically solicits your reactions to this pilot issue. Please take a moment to complete this form, thus helping us to evaluate your needs and determine future directions of this publication.

Please indicate your response to each of the following items by checking or circling the appropriate blank/number which best indicates your reaction. Your comments (Item #12) are greatly appreciated. Thank you.

1. There is a growing NEED for a publication of this kind.

   Yes No

2. The format of this pilot issue

   does not meet my needs 1 2 3 4 5 meets my needs

3. The content of this pilot issue

   does not meet my needs 1 2 3 4 5 meets my needs

4. The ARTICLES/REPORTS were

   too technical 1 2 3 4 5 insufficiently technical

5. Most of the classroom activities in the "Energizing your Curricula" section are

   not practical or appropriate for my classes. 1 2 3 4 5 practical or appropriate for my classes.

6. The Editorial Review Board represents an APPROPRIATE BALANCE between educators and industry personnel.

   Yes No

7. Future issues should

   - ☐ remain the same length
   - ☐ be reduced in length
   - ☐ be expanded in length

8. This publication should be ISSUED

   - ☐ semi-annually
   - ☐ quarterly
   - ☐ bi-monthly
   - ☐ monthly

9. Should more, less or about the same amount of space be devoted to:

	MORE	SAME	LESS
AWARENESS ARTICLES	☐	☐	☐
RESEARCH REPORTS/EVALUATIONS	☐	☐	☐
ENERGY CURRICULAR PROJECTS	☐	☐	☐
"ENERGIZING YOUR CURRICULA"	☐	☐	☐
TEACHER BACKGROUND UP-DATES	☐	☐	☐
MATERIALS REVIEW	☐	☐	☐

10. If THE JOURNAL OF ENERGY EDUCATION were to be distributed on a SUBSCRIPTION BASIS with rates comparable to other journals of this type, would you subscribe?

Yes No

11. Please rate the OVERALL QUALITY of this issue.

Poor 1 2 3 4 5 Excellent

12. OTHER COMMENTS/SUGGESTIONS: _____

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